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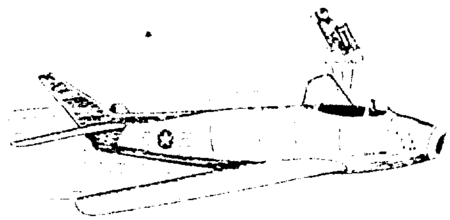

CARTRIDGE ACTUATED DEVICES
FOR AIRCRAFT USE

STATUS REPORT
PROJECT TS 1-15

PITMAN-DUNN LABORATORIES
FRANKFORD ARSENAL
PHILADELPHIA, PA.

1 January 1953 to 30 June 1953

FRANKFORD ARSENAL

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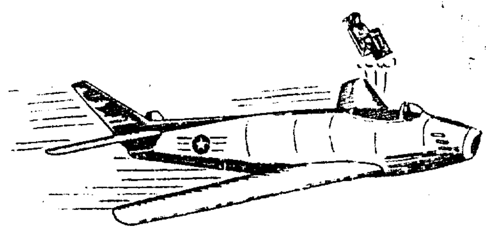

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CARTRIDGE ACTUATED DEVICES
FOR AIRCRAFT USE

9 STATUS REPORT. 1 Jan-30 Jun 53.

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~~1 January 1953 to 30 June 1953~~

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PREFACE

The information contained in this report is a progress summary for the period 1 January to 30 June 1953 of the technical phases of the development program, "Cartridge Actuated Mechanisms for Aircraft Use," Project TS1-15. This report has the following purposes:

a. To serve as a repository for pertinent classified data;

b. To facilitate accumulation of technical data for preparation of final reports;

c. To permit review of separate phases of the development program to insure coordination and review in terms of military objectives.

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CARTRIDGE ACTUATED DEVICES
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SECTION I

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

AIRCRAFT LABORATORY
(WCLSJ-4)

A. Catapults

CATAPULT, AIRCRAFT PERSONNEL CAPSULE, T16
(Project TS1-15-C3)

Project Engineer: A. K. Oechsle, Capt, USAF
Ballistics Phase: H. A. Sokolowski

Authorization: (a) RAD ORDTS 3-3754, OO 121.2/4345, 3 Oct 52;
(b) OO 113/1287, FA 121/16620, 13 Oct 53

OBJECT: The purpose of this development is to design, develop and manufacture Catapult, Aircraft Personnel Capsule, T16, including cartridge and initiator.

STATUS: Wright Air Development Center, Wright Patterson Air Force Base, Ohio, requested the Office, Chief of Ordnance, Department of the Army, to develop a downward capsule separation device on 9 July 1952. On 28 July 1952 the Office, Chief of Ordnance, requested Frankford Arsenal to develop such a device for use on the Republic Aviation Corporation MX-1554B. Performance specifications follow.

Maximum velocity:	50 f/s
Maximum acceleration:	9 g
Maximum rate of acceleration:	125 g/s
Maximum propelled mass:	1000 lb

A tentative delivery date of the first prototype model was 30 September 1953 for installation on the capsule at that time.

On 13 October 1952, MX-1554B was superseded by MX-1554A, a development of XF-103, Republic Interceptor Fighter. On 12 December 1952 the performance specifications were revised as follows:

Velocity:	44 f/s when fired in a system subjected to a −3 g acceleration at −65° F
Maximum acceleration:	12 g at +160° F
Rate of change of acceleration:	125 g/s
Structural strength:	2000 pounds tension and 8000 pounds compression
Propelled mass:	800 pounds
Overall length:	42 17/64 inches
Outer diameter:	2 5/8 inches

Since other items and escape systems under development for Wright Air Development Center carried higher priority, the development of Catapult, Aircraft Personnel Capsule, T16, was delayed.

The ever expanding cartridge actuated devices (CAD) work load has made it necessary to canvas private industry so that development of Catapult, T16, could be placed on contract. Several private concerns were requested to submit preliminary proposals covering research and development phases of this project. Representatives of the Office, Chief of Ordnance, evaluated the proposals, taking into consideration the facilities and personnel available, understanding of research and development problems, geographical location of the company, and cost per man-hour of both engineering and shop time. As a result of this evaluation Frankford Arsenal recommended that Reaction Motors, Inc., Rockaway, New Jersey, be selected to submit a final proposal with the following phases and including individual cost estimates for each phase:

Phase I: Interior ballistic design and design layout of Catapult T16;

Phase II: Detailed design, development and testing of Catapult T16;

Phase III: Manufacture of 25 Catapults, T16, of the final design.

On 9 April 1953 the structural strength requirements were revised to read 3600 (later increased to 6000) pounds compression and 8800 pounds tension. The final proposal was received from Reaction Motors, Inc., dated 19 June 1953. This proposal was accepted and a contract is being negotiated.

The design and development specifications for Catapult, T16, are as follows:

1. Mechanical Components

a. General

The downward ejection of the capsule will be accomplished by the use of two catapults as a unit. This unit will be identified hereafter as Catapult, Aircraft Personnel Capsule, T16, and the cartridge as Cartridge, Catapult, T226. The catapults are to be of the telescoping type, actuated by propellent gas. The catapults may be actuated by two cartridges, one in each catapult, fired simultaneously,* or a single cartridge located in a central chamber. The firing of the cartridge or cartridges is to be initiated by a single source. Tentatively, the designs of the two catapults will be similar in appearance to the Catapult, Aircraft Personnel, T9E3, with the following exceptions:

(1) The base cap of the catapults will have a threaded boss to facilitate installation.

(2) The approximate over-all length will be 42 17/64 inches and the diameter 2 5/8 inches.

*See Appendix A for experimental studies of deviations from exact coincidence in space and time, and dynamic factors of two catapults fired by a single initiator.

(3) The stroke of the catapult will be 76 inches long.

Light weight materials consistent with adequate strength and rigidity shall be used throughout, and the choice of materials shall also be made to prevent damage from rust and corrosion in a salt atmosphere at high humidity. All parts must perform their intended functions over a temperature range of $-65°$ to $+160°$ F, and under all climatic conditions.

The two catapults shall be designed to operate as a unit and shall withstand rupture and leakage when fired locked-shut. In addition, satisfactory operation is required under loads of six g in compression and eleven g in tension. The catapults shall be designed to attach to the capsule being designed by Republic Aviation Corporation for the MX-1554A (XF-103) Airplane.

b. Breech Mechanism

The breech mechanism containing the firing mechanism shall be attached to the inner tube. It shall be protected from the intrusion of dirt, moisture and other foreign matter.

c. Firing Mechanism

The firing mechanism may be of the percussion or electrical type of ignition and may be either mechanically, electrically, or gas operated. In the event a dual cartridge design is used, the cartridges are required to fire concurrently.

d. Catapult Locking Mechanism

The mechanism for locking the catapults to the aircraft structure shall be designed so that release of both catapults is accomplished simultaneously by the movement of the firing pins or by any positive means of equal simplicity. The mechanism shall be so designed that it cannot be inadvertently released, either by maneuvers of the aircraft producing loads in compression up to six g and tension up to 11 g on the catapults, or by the pilot performing his normal duties. The locking mechanism must be capable of retaining a capsule-man weight of 800 pounds ± five per cent under loads previously specified.

e. Safety Features

The design shall incorporate a safety device or feature which will prevent ejection of the capsule if one or both catapults should be fired by means other than the normal procedure (viz, cook-off in a burning airplane, severe jolt from crash landing, etc). A suitable safety device or feature shall be provided so that one or both catapults cannot be fired until the capsule hatch door has been jettisoned or is in the emergency open position. Means shall be provided for making this device inoperative at the pilot's discretion. Electrical shielding shall be required if the system is electrically initiated and fired. The catapults shall be designed so that they do not interfere with the operation of the parachute. Design of the catapult shall incorporate a feature to permit safe shipment, storage and handling. The safety feature should be manually removable during installation.

2. Ballistic Requirements

a. Velocity and Acceleration

The cartridge shall be designed to have satisfactory uniform ballistic characteristics with the probability of malfunction less than 1/250,000 at any temperature between −65° and +160° F. It shall be capable of ejecting an 800 pound ± five per cent capsule-man weight from the aircraft with a minimum velocity of 44 f/s when subjected to a −3 g acceleration at −65° F. The upper velocity limit will be determined by the acceleration limits. The acceleration shall not exceed 12 g at any temperature over the temperature range. The rate of change of acceleration shall not exceed 125 g/s at any temperature within the specified range. For purposes of test, a solid, nondeformable, dead weight shall be used ranging from 800 to 2400 pounds.

b. Operational Delay

No operational delay shall occur on any rounds. An operational delay is defined as occurring when the time from the instant the catapult latches are entirely open until the chamber pressure begins to rise exceeds 0.06 seconds.

c. Velocity Uniformity

The ejection velocity of cartridges manufactured under production conditions and fired at each of the three temperatures (−65°, +70° and +160° F) shall be as follows:

(1) At +160° F the standard deviation of individual values of the indicated velocities for a group of ten shall not exceed 1.6 f/s.

(2) At +70° F the standard deviation of individual values of the indicated velocities for a group of ten shall not exceed 1.6 f/s.

(3) At −65° F the standard deviation of individual values of the indicated velocities for a group of ten shall not exceed 2.5 f/s.

3. Cartridges

a. Primer

The primer shall be of the percussion or electric type, as indicated by the design. The primers shall be furnished by the US Government.

b. Moisture Proofness and Service Life

The cartridge must stand up, remain moisture proof, and give satisfactory ballistic performance after long time storage and cycling between temperature extremes and variations in atmospheric pressures to be encountered between sea level and high altitudes. Cartridges shall be tested to determine the adequacy of the seal.

c. Rough Handling and Safety

(1) Jolt

Cartridges shall be subjected to standard jolt test prescribed for fuzes, MIL-STD-300. Cartridges must not fire during test; parts must not break, become loose, distorted, or out of place. Cartridges must be moisture proof and must pass ballistic requirements after test.

(2) Vibration

Cartridges shall be subjected to vibration tests prescribed for fuzes, MIL-STD-303. Cartridges must not fire during this test; parts must not break, become loose, distorted, or out of place. Cartridges must be moisture proof and must pass ballistic requirements after vibration tests.

d. Moisture Content

The moisture content of black powder and other propellent or explosive components as well as the total volatile content of the propellant shall be in accordance with the applicable specifications.

e. Corrosion Resistance

All parts shall be plated or coated to withstand corrosion under high humidity conditions in a salt atmosphere as prescribed for environmental testing of aeronautical and associated equipment, MIL-E-5272 (USAF). Aluminum parts shall be anodized, MIL-C-5541, and chromate treated. Coatings used shall not crack, peel off, become soft or sticky, or otherwise fail within service ranges of temperature and humidity.

APPENDIX A

APPENDIX A
(Project TSI-15-C3)

Experimental Comparison
of
Motions of Two Catapults
Fired by a Single Initiator

A study was made to determine whether two catapults fired with the same initiator moved sufficiently closely together for possible use in parallel. A slide wire bridge recorded travel and difference in travel for two Catapults with Cartridge, Aircraft Personnel, M4, each propelling a 305.5-pound load, each fired through a separate 25-foot hose from a test Initiator, Catapult or Canopy Remover, T8. Previous work (Status Report, Project TS1-15, September 1952, Section VII) has shown that the difference in firing time between catapults for a similar configuration is not more than six milliseconds.

At 32 inches travel, the largest travel at which the instrumentation operated, the difference in travel was approximately two inches. Full firing data follow.

Firing Data of the Simultaneous Firing of Two Catapults, M4

Powder Description

Powder type	5130.16
Outer diameter of grain	0.3 inch
Web	0.11 inch
Number of perforations	1
Igniter grains and granulation	50 A1
Powder charge	543 grams
	541 grams
Diaphragm	5 mils (magnesium)
Length of pieces	1.0 inch
Number of pieces	31

Performance Data

Velocity (f/s)	Max Accel (g)	Initial Accel (g)	Rate of Accel (g/s)	Max Pressure (psi)	Ignition Delay (sec)	Burning Time (sec)
38.10	8.2	4.3	64	1290	0	0.21
40.39	8.8	3.7	83	1370	0	0.20

Fired at 70° F.

ENGINEERING STUDIES AND TESTS OF TRUNNION FOR CATAPULT WITH CARTRIDGE, AIRCRAFT PERSONNEL, M5, FOR THE PURPOSE OF STRENGTHENING THE OUTSIDE TUBE THREAD JOINT (Project TS1-15-C5)

Project Engineer: G. P. Miller
Ballistics Phase: P. W. Sieck, Pfc

Authorization: (a) 00 452.1/49, FA 452/144.1
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To perform engineering studies to improve the strength of the trunnion-outside tube thread joint on Catapult with Cartridge, Aircraft Personnel, M5, and to perform necessary static tests.

STATUS: A letter, dated 26 February 1953, from Wright Air Development Center requests that the following test be conducted on Catapult with Cartridge, Aircraft Personnel, M5. Static tests should be conducted on bending of Catapult, M5, to check the strength of the trunnion thread joint.

It was decided to contract the study and testing of the trunnion thread joint. This was made part of a contract[1] with Power Generators, Limited, Trenton, New Jersey. The award was dated 13 August 1953.

This study is in the evaluation stage. Several designs are now under consideration, the results of which are not yet available.

[1]Contract DA-36-034-ORD-1453-RD.

IMPROVEMENT TO
CATAPULTS WITH CARTRIDGE, AIRCRAFT PERSONNEL,
M3, M4, AND M5
AND TO
REMOVER WITH CARTRIDGE, AIRCRAFT CANOPY, M3
(Project TSI-15-C10)

Project Engineer: C. Sterrett
Ballistics Phase: J. L. Helfrich

Authorization: 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To improve the hose connection to gas-fired catapults and removers.

STATUS: Limited procurement and installation of catapults and removers having gas initiated firing mechanisms have indicated that the present pipe threaded hose connection to these units is unsatisfactory. First, leakage has developed at the hose fitting because the threads in the aluminum block rupture when the steel fitting is tightened in place. Second, the pipe threaded part does not permit qualification of the fitting direction. At present it is apt to be pointed in a direction which is inaccessible for hose installation. In fact, some aircraft manufacturers have qualified the threads on the fitting before assembling it to the unit so that this deficiency does not present an installation problem.

The Air Force suggested that the project personnel consider two proposals: (1) the incorporation of an AN type fitting boss in the block, and (2) the design of a universal type fitting for attaching to the present pipe threaded port.

The first proposal the Air Force suggested concerned the modification of several blocks for the catapults and removers by incorporating an AN type fitting boss and then testing these blocks at high and low temperatures. A compression or tension test would also be performed on this piece. A requirement for this modification is that it should not require more installation space.

Frankford Arsenal has prepared drawings for modification of the blocks on Catapults with Cartridge, Aircraft Personnel, M3, M4, M5 and Remover with Cartridge, Aircraft Canopy, M3. This was accomplished by relocating the hole connecting the firing pin chamber and the threaded boss; providing ample metal thickness for the AN-type boss, Drawing AND 10050-4. Blocks have been manufactured to these modifications.

The second proposal suggested was to design a universal fitting for attaching to the present pipe-threaded port. Universal commercial fittings are not available for attaching to pipe threads, only to straight threads.

Several fittings have been built and sent to Wright Air Development Center for comment and evaluation. If these fittings are satisfactory, it is anticipated the Air Force will procure a number for use on catapults at present in production.

Tests will be made on these units after funds have been received, and Wright Air Development Center will be notified of the results.

STUDY OF SHEAR PIN AND HOSE LENGTH IN CATAPULTIC DEVICES
(Project TSI-15-C25)

Project Engineer: L. E. Garfield, Pfc
Mechanical Engineering Phase: J. J. Gricius

Authorization: 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To evaluate the effect of shear pin material, size, and hose length required for the functioning of gas-operated Catapults with Cartridge, Aircraft Personnel, M3, M4, and M5 and Remover with Cartridge, Aircraft Canopy, M3.

STATUS: An experiment was conducted to provide an estimate of the probability of a malfunction of a catapult system initiated through 10 ft of pneumatic pressure hose. It was based on the use of the statistical technique of increased severity tests. On the limited sample available, the distribution of fires vs length of hose did not agree with a normal error law of distribution. It is suspected that this is attributable to large experimental errors and the small sample size. Predictions based on tests at 11.5, 12.5, and 14.5 ft of hose indicate a probability of failure at 10 ft of 1 in 1000. This is a conservative estimate; the chance of a failure at a 10 ft length is probably less than this value.

In the application of increased severity tests the assumptions are made that the fraction of items failing are normally distributed with respect to the pressure or length of hose and that the data are randomly collected, i e, that the test units are not affected by the use and reuse.

Results obtained with several lengths of hose are summarized as follows.

Hose Length (ft)	*Sample Size*	*Successes*	*Failures*	*Fraction Failing*
11.5	31	31	0	0.0
12.5	14	7	7	0.5
13.5	8	6	2	0.25
14.5	15	3	9	0.75

The sample data obtained at 13.5 feet were of an exploratory nature and not utilized in the final calculations. A plot was made on normal probability paper of the data at 12.5 feet and 14.5 feet. Extrapolation of a linear line through these points would indicate a probability of failure at 11.5 feet of about 0.38. Since the experimental value at 11.5 feet was entirely inconsistent with this extrapolated value, it is strongly indicated that the sensitivity data is not normally distributed. The curve is probably concave upward as though asymptotic to the probit or probability of failure coordinated.

Since no failures to fire were obtained at 11.5 feet, it was not possible to place this point on the curve. As an approximation, the data obtained at this length were used to estimate an Expected Value of the fraction failing at this hose length. This was accomplished by calculating the probability, using binominal probability law, of obtaining a sample of 31 items with no failures from populations with Average Quality Level (AQL) of 0.1, 0.022, 0.01, 0.0015 and 0.001 fraction defective. These values, together with the probability of obtaining one or more failures in the same sample of 31 items, are as follows.

AQL of Population	*Probability of Obtaining Number of Failures Indicated in Sample of 31 Items*			
	0	*1*	*2*	*3*
0.1	0.038	0.104	0.219	0.232
0.022	0.500	0.349	0.118	0.025
0.01	0.730	0.229	0.035	0.003
0.0015	0.945	0.050		
0.0010	0.972	0.030		

In order to be quite conservative, the Expected Value at 11.5 feet was taken as the AQL of the population for which the probability of obtaining a sample of 0/31 defectives was 0.5. The AQL of this population is shown above to be 0.022. This point was then utilized for the 11.5-ft hose length and a least squares-line was calculated for this point and the points at 12.5 and 14.5 feet. By extrapolation of this line to the 10-ft hose length, an estimate of the quality to be expected at this length was found to be 0.001, i e, one failure in a thousand.

Referring again to the table shown above, it will be seen that the probability of obtaining one failure to fire in a sample of 31 items is rather high for both the 0.022 and the 0.01 AQL level. This indicates that one would expect the sample of 31 items taken at 11.5-ft lengths to have given one or more defectives if the true quality level were 0.01 or higher. With this in mind, an estimate was made of the AQL of a population that would have given a sample of 31 in which the probability of obtaining one defective was only 0.05. This AQL turned out to be 0.0015. If this value were used for the Expected Value at 11.5 feet, the fraction defective at 10 feet would have been less than one in 10,000. This is in agreement with the apparent tendency of the plotted curve to become asymptotic to the probit coordinate.

Future Work

A systematic study of the probability of initiation in elements of gas-initiated escape systems is to be conducted under Program C101, entitled, "Reliability of Gas-Initiated Escape Systems," and Program C25 has been incorporated thereunder.

SECTION I

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

AIRCRAFT LABORATORY
(WCLSJ-4)

B. Removers

REDESIGN OF REMOVER WITH CARTRIDGE, AIRCRAFT CANOPY, M1A2 (Project TS1-15-C7)

Project Engineer: G. P. Miller
Ballistics Phase: L. E. Garfield, Pfc

Authorization: (a) 00 452.1/45, FA 452/1418, 11 Mar 53; 1st Ind, 6 May 53
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To redesign Remover with Cartridge, Aircraft Canopy, M1A2, in order to eliminate the requirement for Exactor, Canopy Remover, M1.

STATUS: A letter from Wright Air Development Center, dated 6 February 1953, states service experience indicates Remover with Cartridge, Aircraft Canopy, M1A2 (combination of Remover with Cartridge, Aircraft Canopy, M1A1, Initiator with Cartridge, Catapult and Canopy Remover, M3, and Exactor, Canopy Remover, M1) should be simplified. From an operational, maintenance, and safety standpoint, it would be desirable to eliminate the exactor. This modified remover should have the same performance characteristics as the Remover, M1A1. It was requested that Frankford Arsenal investigate the feasibility of the above suggestion.

It was decided to contract the design and manufacturing phases of this development. Accordingly, proposals for bidding were prepared and bids requested. The contractor is Power Generators, Limited,[1] Trenton, New Jersey. The award was made on 13 August 1953.

The project is only in the preliminary sketch stage. Several ideas are being discussed currently.

[1] Contract DA-36-034-ORD-1453-RD.

SECTION I

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

AIRCRAFT LABORATORY
(WCLSJ-4)

C. Initiators

CHARGE REVISION, DELAY-INITIATORS, T13 AND T14 (Project TS1-15-C22)

Project Engineer: J. L. Helfrich
Mechanical Engineering Phase: J. J. Gricius

Authorization: (a) FA 453/1273, 27 Aug 52
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To raise the performance level of Delay-Initiators, T13 and T14 to equal the performance level of Initiator with Cartridge, Catapult and Canopy Remover, M3.

STATUS: The mechanically fired Delay-Initiator, T14, and the gas-fired Delay-Initiator, T13, have been designed and developed to function a lap belt release after personnel ejection from an airplane. The selected charge was intended to function the lap belt release with short lengths of flexible hose (approximately three ft). In view of the anticipated need for a delay initiator capable of performance similar to that of Initiator with Cartridge, Catapult and Canopy Remover, M3, and Initiator with Cartridge, M5, consideration has been given to increasing the propellent charge in the Cartridge, Delay-Initiator, T217, case (cartridge for Delay-Initiators, T13 and T14) to the point where the delay initiator will duplicate the present Initiator, M3, performance.

This change to a standardized performance level should lessen future design problems and avoid installation difficulties. A charge revision program to accomplish the above objective has been outlined.

Since Cartridge, T217, with delay element could comfortably contain the present propellent charge Cartridge Initiator, M38 (cartridge for Initiator, M3), this propellent charge was evaluated using the existing design of Initiator, T14. The following table gives the averages of five firings at −65° F, three firings at 70° F, and five firings at 165° F for various lengths of AN 6271-4 flexible hose. In each firing the initiator, cartridge, and hose were at the temperature specified.

Propellent charge: 2.8 grams 5280 + 1 gram A4 black powder

Hose Length (ft)	*-65° F*	*Pressure* at 70° F*	*160° F*
2	3450	3450	3690
4	2570	2910	2970
6	1830	2140	2160
8	1460	1810	1760
10	1080	1390	1390
12	840	1130	1180
14	700	910	970
16	560	790	850
18	430		740

*Average pressure at end of hose, using pressure blocks with volume comparable to volume existing in gas-initiated catapults.

A graph (Figure 1) is included showing plot of data with a line drawn through the minimum (not average) values of pressure measured at −65° F. The apparent inversion of average pressure relationships at certain hose lengths exists because the small number of firings does not completely evaluate the effects of the spread in performance at a given temperature. Plotted on the same graph is the minimum measured pressure for a given hose length for the Initiator, M3.

CHARGE REVISION,
INITIATOR WITH CARTRIDGE, CATAPULT AND CANOPY REMOVER, M3,
AND
INITIATOR WITH CARTRIDGE, M5
(Project TSI-15-C26)

Project Engineer: J. L. Helfrich
Mechanical Engineering Phase: J. J. Gricius

Authorization: (a) Verbal Request from Wright Air Development Center and Correspondence, FA 452/1346
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To improve the performance of Initiator with Cartridge, Catapult and Canopy Remover, M3, and Initiator with Cartridge, M5.

STATUS:

1. Initiator with Cartridge, Catapult and Canopy Remover, M3 (Cartridge, Initiator, M38)

a. Charge Development
(Complete data are contained in Table I.)

Test firings were conducted in Initiator, M3, employing a cartridge containing eight pieces of propellant, Lot 299 (full capacity charge), and one gram of A4 black powder as the booster charge. The initiator was connected directly through 15 feet of flexible hose to the exactor test block and fired at temperatures of −65°, 70°, and 160° F. The results are summarized below.

Pressure (psi)	*Temperature (°F)*
410	−65
450	70
540	160

Since this performance compares unfavorably with that of the standard Cartridge, M38, Lot 299 is considered unsuitable for this application. Additional charge studies are planned using propellants of smaller granulation and higher impetus.

b. Effect of 180° Bend in Flexible Hose
(Complete data are contained in Table II.)

To determine whether a severe bend will influence the pressure delivered to an exactor or thruster, pressure measurements were made at the down stream end of the hose under several conditions. The hose was formed into a U shape (180° bend) with a bend diameter of 3 1/4 inches. Using an Initiator, M3, at one end, pressure was measured in a pressure block at the other end with hose lengths (total) of one, two, three and four feet. Similar measurements were made with straight hoses of these lengths for comparison. A summary of the results follows.

	Pressure Measured at −65° F (psi)			
Hose length (ft)	1	2	3	4
Straight	6530	5630	4500	3790
U shape	6580	5385	4455	3740

	Pressure Measured at 160° F (psi)			
Hose length (ft)	1	2	3	4
Straight	7140	5840	5060	4305
U shape	7360	6235	5135	4020

These data indicate no significant effect of such bend in tubing.

c. Effect of Severe Hose Blocking

It was considered to be of interest to determine the pressure produced by an Initiator, M3, when connected (inadvertently) to a completely plugged system. To simulate conditions of greatest severity, the initiator was heated to 160° F and the system was plugged at the initiator outlet so that no expansion volume was available beyond the initiator chamber. This was accomplished experimentally by connecting the initiator directly to a pressure block whose volume was filled with grease. Three shots fired under these conditions produced pressures of 10,430, 10,150, and 10,520 psi, respectively. Design pressure is specified as 1000 psi.

d. Charge Revision of Initiators, M3 and M5

In view of a change in the size of the firing pin shear pin in the gas-operated Catapults with Cartridge, Aircraft Personnel M3, M4 and M5, and in the Remover, with Cartridge, Aircraft Canopy, M3, the assembly hose length of the connecting hose AN 6271-4 between the catapult or remover and the initiator is limited to ten feet. In order to increase the reliability of these and other gas-operated devices and to increase the effective distance (hose length) over which they may be used in conjunction with Initiator, M3, an increase of the propellent charge in the initiator will be required. In addition, Wright Air Development Center has requested that pressure-length relationship with tubing lengths up to four feet be determined with hose AN 6292-4 which has a higher bursting pressure than AN 6271-4.

An experimental program has been designed to develop the propellent charge required and to study the pressure-tube length relationship.

e. Effect of AN 6271-4 vs 1509A-3/16 x 2*

With a view toward increasing the over-all efficiency of the gas-operated initiator systems, experimental evaluations are made of new types of flexible hydraulic tubing. Using the Initiator, M3, with Cartridge, M38, as the gas source, pressure comparisons were made at the end of 36-inch samples of 1509A-3/16 x 2 hose and the current standard hose, AN 6271-4. The pressure measurements were made in a standard pressure block with the complete initiator system conditioned at temperatures of -65°, 70° and 160° F.

The measurements indicate that the new type hose (1509A-3/16 x 2) has better pressure transmission properties than the current standard hose. Pressures were 11 per cent higher on the average, based on four measurements at each temperature with each of the two hose types. The average values are as follows:

Temperature (°F)	*Pressure (psi)*		*Pressure Difference (%)*
	1509A-3/16 x 2	*AN 6271-4*	
-65	3910	3520	11
70	4300	3910	10
160	4370	3880	12

The above data were obtained with 36 inch straight lengths of tubing. An additional evaluation was made with 30 inch lengths helically coiled on a three inch diameter. This was for the purpose of determining the pressure transmission properties through bends. Under these conditions the difference between the two hose types was not significant, based on four firings of each type at each temperature. The average values follow.

Temperature (°F)	*Pressure (psi)*	
	1509A-3/16 x 2	*AN 6271-4*
-65	4090	4120
70	3975	4060
160	4355	4310

*Manufactured by Aeroquip Company.

All of the data are based on repeated firing on a single sample of each type of tubing. Although no significant trends are apparent in any of the four-shot series, the effects of repeated firing on the pressure transmission properties are not known accurately and the data, particularly those of the latter shots, may have been influenced by these conditions. Round by round data are given in Table III, Initiator, M3, rounds Nos. 651 to 698, incl.

2. Initiator with Cartridge, M5, (Cartridge, Initiator, M38)

a. Firing Pin Housing Vent Leakage

Evidence was obtained indicating that gas leakage occurs from Initiator, M5, chamber back through the ball check valve on the firing pin housing. The effect of such leakage on the pressures produced is appreciable, approximately 200 psi, and it has been recommended that the vent in the firing pin housing, and the check valve be deleted from the design of the Initiator, M5.

The vent arrangement was originally included to allow venting of the air trapped in front of the firing pin to avoid cushioning of the firing pin blow. Under the conditions in which the vent was plugged, no misfires occurred.

In the following tests the Initiator, M5, was fired by an Initiator, M3, through a 15 ft length of hose. Tests were conducted at 70° F and pressures were measured under Initiator, M5, acceptance test conditions.

	Pressure in Test Fixture (psi)		
	No Ball in Vent	*One Ball in Vent (Std)*	*Vent Plugged*
Initiator, M5, direct to pressure fixture	5320	5595	5780
Initiator, M5, to pressure fixture through 15-ft hose	595*	630*	835

*This group contained pressures low enough (under 600 psi) to cause failure of a lot of Initiators with Cartridge, M5.

Round by round data are given in Table IV (Initiator, M5, rounds 840 to 849, incl, 875 to 884, incl, 902 to 911, incl).

Note: Initiator, Catapult and Canopy Remover, T4, has been standardized as Initiator with Cartridge, Catapult and Canopy Remover, M3

Initiator, Thruster or Catapult, T5, will be standardized as Initiator with Cartridge, M5.

Cartridge Initiator, T129, will be standardized as Cartridge Initiator, M38.

Table I. Charge Development, Initiator, M3

(Eight pieces propellant, Lot 299 (full capacity charge) and one gram A4 black powder as booster charge)

Set up: 15 ft. flexible hose; exactor test block

Round No.	*Temperature (°F)*	*Hose Length (ft)*	*Pressure (psi)*	*Time (sec)*
708	70	15	420	0.036
709	"	"	510	0.036
710	"	"	440	0.038
711	"	"	470	0.038
712	"	"	420	0.038
713	−65	"	390	0.042
714	"	"	380	0.044
715	"	"	430	0.036
716	"	"	440	0.034
717*	"	"	210	0.042
718	165	"	500	0.042
719	"	"	580	0.040

*Leaked

Neg. #24498-60
R-1183

Table II. Test of Initiator, M3 (Cartridge, M36), 180° Bend vs No Bend in Hose

Set up: 180° bend					Set up: No bend				
Round No.	Temperature (°F)	Hose Length (ft)	Pressure (psi)	Time (sec)	Round No.	Temperature (°F)	Hose Length (ft)	Pressure (psi)	Time (sec)
761	165	1	7290	0.018	793	-65	1	6670	0.024
762	"	"	7400	0.018	794	"	"	6590	0.024
763	"	"	7340	0.018	795	"	"	6350	0.026
764	"	"	7420	0.018	796	"	"	6520	0.020
765*	165	2	6220	0.017	797	-65	2	4990	-
766	"	"	6140	0.016	798	"	"	5710	0.020
767	"	"	6290	0.020	799	"	"	5630	0.020
768	"	"	6290	0.018	800	"	"	5550	0.024
769	165	3	5160	0.020	801	-65	3	4750	0.023
770	"	"	5410	0.017	802	"	"	4590	0.022
771	"	"	5240	0.018	803	"	"	4260	0.022
772	"	"	4790	0.020	804	"	"	4590	0.022
773	165	4	3820	0.022	805	-65	4	4100	0.023
774	"	"	4120	0.021	806	"	"	3950	0.020
775	"	"	4190	0.020	807	"	"	3650	0.024
776	"	"	4190	0.020	808	"	"	3480	0.026
777	-65	1	6720	0.020	809	165	1	7320	0.015
778	"	"	6360	0.020	810	"	"	7160	0.016
779	"	"	6440	0.020	811	"	"	6870	0.015
780	"	"	6790	0.020	812	"	"	7160	0.015
781	-65	2	5460	0.024	813	165	2	5990	0.016
782	"	"	5460	0.020	814	"	"	5760	0.016
783	"	"	5460	0.024	815	"	"	5760	0.016
784	"	"	5160	0.023	816	"	"	Misfire (no record)	
785	-65	3	4360	0.025	827	165	3	4790	0.019
786	"	"	4510	0.023	828	"	"	5540	0.018
787	"	"	4430	0.024	829	"	"	5160	0.017
788	"	"	4720	0.024	830	"	"	4710	0.019
789	-65	4	3650	0.026	831	165	4	4420	0.016
790	"	"	3830	0.024	832	"	"	4190	0.017
791	"	"	3740	0.026	833	"	"	4490	0.020
792	"	"	3740	0.024	834	"	"	4120	0.022

*Leaked around "O" ring.

Neg. #24498-61
R-1183

Table III. Test of Initiator, M3 (Cartridge, M38), 1509A-3/16x2 vs AN-6271-4 Hose

Set up: Hose out straight; pressure exactor block

Round No.	Type Hose	Temperature (°F)	Hose Length (ft)	Pressure (psi)	Time (sec)
651	1509A-3/16x2	70	3	* 4020	0.028
652	1509A-3/16x2	"	"	* 3840	0.024
653	1509A-3/16x2	"	"	4240	0.024
654	1509A-3/16x2	"	"	4370	0.022
655	AN-6271-4	"	"	3880	0.024
656	AN-6271-4	"	"	3810	0.024
657	AN-6271-4	"	"	3990	0.024
658	AN-6271-4	"	"	3960	0.024
659	1509A-3/16x2	165	3	4450	0.020
660	AN-6271-4	"	"	3950	0.022
661	1509A-3/16x2	"	"	4490	0.020
662	AN-6271-4	"	"	3780	0.022
663	1509A-3/16x2	"	"	4180	0.024
664	AN-6271-4	"	"	3990	0.024
665	1509A-3/16x2	"	"	4350	0.022
666	AN-6271-4	"	"	3820	0.022
667	1509A-3/16x2	-65	3	4100	0.022
668	AN-6271-4	"	"	3500	0.022
669	1509A-3/16x2	"	"	3820	0.022
670	AN-6271-4	"	"	3660	0.024
671	1509A-3/16x2	"	" ***	3890	0.024
672	AN-6271-4	"	"	3530	0.020
673	1509A-3/16x2	"	"	3820	0.024
674	AN-6271-4	"	"	3460	0.024

Set up: Hose coiled around 3 in. diameter pipe; pressure exactor block

Round No.	Type Hose	Temperature (°F)	Hose Length (ft)	Pressure (psi)	Time (sec)
675	1509A-3/16x2	-65	3 **	3680	0.022
676	AN-6271-4	"	"	3750	0.020
677	1509A-3/16x2	"	30 in.	4110	0.024
678	AN-6271-4	"	" "	4150	0.025
679	1509A-3/16x2	"	" "	4110	0.020
680	AN-6271-4	"	" "	4060	0.026
681	1509A-3/16x2	"	" "	4060	0.021
682	AN-6271-4	"	" "	4150	0.020
683	1509A-3/16x2	165	30 in.	4340	0.018
684	AN-6271-4	"	" "	4380	0.019
685	1509A-3/16x2	"	" "	4400	0.020
686	AN-6271-4	"	" "	4300	0.018
687	1509A-3/16x2	"	" "	4260	0.020
688	AN-6271-4	"	" "	4300	0.019
689	1509A-3/16x2	"	" "	4420	0.021
690	AN-6271-4	"	" "	4260	0.022
691	1509A-3/16x2	70	30 in.	4070	0.020
692	AN-6271-4	"	" "	4140	0.024
693	1509A-3/16x2	"	" "	4020	0.020
694	AN-6271-4	"	" "	3990	0.024
695	1509A-3/16x2	"	" "	3960	0.022
696	AN-6271-4	"	" "	4000	0.024
697	1509A-3/16x2	"	" "	3850	0.020
698	AN-6271-4	"	" "	4110	0.021

Note: AN-6271-4 tube is more flexible at -65° F.

* Small leak exactor.
** Tube blew at chamber.
*** Leaked exactor end.

Table IV. Effect of Firing Pin Housing Vent Leakage on Pressures Produced by Initiator, M5

Set up: Direct to acceptance test fixture

No Ball in Vent		*One Ball in Vent*		*Vent Plugged*	
Round No.	*Fixture Pressure (psi)*	*Round No.*	*Fixture Pressure (psi)*	*Round No.*	*Fixture Pressure (psi)*
907	5340	902	5797	880	5720
908	5340	903	*	881	5870
909	5570	904	5724	882	6010
910	5207	905	5657	883	5720
911	5133	906	5207	884	5570

Set up: To acceptance test fixture through 15 ft hose

No Ball in Vent		*One Ball in Vent*		*Vent Plugged*	
Round No.	*Fixture Pressure (psi)*	*Round No.*	*Fixture Pressure (psi)*	*Round No.*	*Fixture Pressure (psi)*
875	610	845	560	840	820
876	560	846	650	841	850
877	630	847	560	842	870
878	590	848	440**	843	800
879	590	849	750	844	770**

*No Record
**Hose blew

SECTION I

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

AIRCRAFT LABORATORY
(WCLSJ-4)

D. Exactors

STRENGTH OF INITIAL LOCK
AND OF
PISTON ASSEMBLY OF EXACTOR, CANOPY REMOVER, MI
(Project TS1-15-C9)

Project Engineer: N. Waecker
Ballistics Phase: P. W. Sieck, Pfc

Authorization: OO 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To improve the design of the piston assembly and to determine strength range of the initial lock and of the piston assembly.

STATUS: Limited procurement of Exactors, Canopy Remover, M1, for development purposes has indicated that manufacturing tolerances permit a wide variation in the strength of the initial lock and that the strength of the piston assembly may not always be above the 400 pounds specified on the standardized drawings.

In order to determine the strength of the initial lock, six units, consisting of the pieces functioning as the lock, will be assembled with the widest tolerances possible and six units assembled with the narrowest tolerances possible. Simple compression or tension tests will be performed.

Two modifications on the piston assembly will be tested to determine whether the strength is improved. The first test will consist of substituting a snap ring for the swaging arrangement at present being used. The second test will be made substituting a key for the swaging. Simple compression on tension tests will be performed.

Note: Exactor, Canopy Remover, T1, has been standardized as Exactor, Canopy Remover, M1.

SECTION I

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

AIRCRAFT LABORATORY
(WCLSJ-4)

E. Escape Systems

DEVELOPMENT OF ESCAPE SYSTEM FOR B-52 AIRPLANE
(Project TSI-15-CI)

Project Engineer: J. J. Gricius
Ballistics Phase: H. A. Sokolowski

Authorization: (a) 00 452.1/1185, FA 452/966-2, LC 78283, 8 Nov 51
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop cartridge actuated mechanisms for B-52 Airplane System.

STATUS: Initial requirements for the B-52 Airplane escape system were established during discussions at Frankford Arsenal between personnel of Wright Air Development Center, Boeing Airplane Company and Frankford Arsenal on 29 August 51 and 2 November 51. Development, based on these tentative requirements, was initiated and data obtained.

In order to complete the development, methods have been devised for correcting troublesome thruster problems, such as: (1) failure of piston and mounting lug when fired under no load, (2) metal erosion due to propellent gas, (3) gas leakage, (4) initial lock and (5) final lock. In addition, criteria for charge development were established. In order to meet the initial requirements and include a final lock, an initial lock and a gas by-pass port in each of the various actuators required for the escape system, development of a group of actuators known as Thrusters, Cartridge Actuated, T1, T2, T3, and T4 was initiated. These are shown in Figures 2 and 3. Thrusters T1, T2, and T3 have been obsoleted. Thruster, T4, has been identified as Thruster with Cartridge, M4, for interim use in the Republic Aviation Corporation F-84F Airplane under Project TS1-15-C8.

On 28 January 1953 a program review was held at Frankford Arsenal. Personnel of Wright Air Development Center, Boeing Aircraft Company and Frankford Arsenal were present. As a result it was found that Frankford Arsenal developments were in accordance with the military requirements set by the Air Force. However, these requirements were not completely applicable to the B-52 Airplane escape system. Definite military requirements were established during this conference.

Frankford Arsenal developments have been proceeding in accordance with requirements established during this conference and subsequent conferences held at Frankford Arsenal 2 March, 16 April and 26 May 1953. The development procedures have been divided into three phases.

Phase I. Develop the units to meet the general and specific military requirements.

Phase II. Evaluate the performance of each unit in a configuration consisting of other units, base, fittings, etc., simulating an installation. Recommend standardization after completion of successful tests.

Phase III. Assess the units to provide data applicable to the design of future units, provide data for specifications, data for the Air Force and Air Force frame manufacturers to be utilized in determining the kinetics of aircraft installations, preparation of Notes on Development Type Materiel and compilation of data in a final report.

Acceptance of units by the Air Force for standardization is not made until completion of ground and flight tests.

Concurrent with Frankford Arsenal developments, ground and flight tests are being conducted by Boeing Airplane Company and Weber Aircraft Co. Delivery of units to the aforementioned for these tests are being met by Frankford Arsenal in accordance with the latest delivery schedule as set up at the conference held at Frankford Arsenal 26 May 1953.

MILITARY REQUIREMENTS

1. General

The B-52 Airplane consists of three systems: (a) upward seat ejection (Figure 4), (b) downward seat ejection (Figure 5), and (c) tail cone jettisoning (Figure 6). Previous to recommending standardization, Frankford Arsenal is required to evaluate the performance of each unit in simulated tests agreed to at conferences between Air Force, aircraft manufacturers and Frankford Arsenal personnel.

In the previous report, Status Report, Dec 1952 to Jan 1953, p 23, revised requirements applicable to the B-52 Airplane escape system were outlined. Since then the following additional requirements have been introduced:

a. Vibration

All gas-fired catapults, removers, initiators, and thrusters shall meet the general requirements specified by Wright Air Development Center, WCLSJ-4 (ltr FA 452/1522, 15 Apr 53 and ltr ORDBA-LC 5450, 30 Jun 53).

b. All thrusters shall: (1) not fail when fired under no load, (2) withstand maximum pressures when fired locked-shut and (3) remain initially locked.

c. All initiators shall: (1) withstand maximum pressures when fired locked-shut and (2) remain assembled under the specified vibrations.

d. All units shall meet the applicable requirements of Specification MIL-E-5272A (USAF) for environmental conditions.

Specific requirements follow.

a. Thruster, Cartridge Actuated, T1E1, and Cartridge, Thruster, T181

In addition to the requirements specified in the previous report for the hatch jettison for upward and downward seat ejection, a minimum effective force of 3200 pounds at 0.40 inch is necessary.

b. Thruster, Cartridge Actuated, T2E1, and Cartridge, Thruster, T182E1

A final lock is not required for seat positioning for downward seat ejection. The maximum final velocity permitted is 5 f/s, and is obtained by a buffer system. The thruster stroke is 5.7 inches.

c. Delay-Initiator, T13, and Cartridge, Delay-Initiator, T217

The 2 1/2 ± 1/4 second delay cartridge is acceptable for the tail cone jettisoning system.

d. Other units

Requirements for all other units as specified in the previous status report remain unchanged.

2. Development

a. Thruster, Cartridge Actuated, T1E1, and Cartridge, Thruster, T181 (Figures 7, 8, and 9)

(1) Hatch Jettison for Upward and Downward Seat Ejection.

Tests have been conducted by simulating the loads in a test fixture by shearing pins at the required positions. The tentative charge selected for Cartridge, T181, is 2.0 grams of propellant, M10, Lot PA 30187, and 1.25 grams of A4 granulation black powder igniter. A series of ten firings at each of the temperatures yielded the following average results.

Temperature	*65° F*	*70° F*	*160° F*
Time to maximum thrust (sec)	0.007	0.006	0.005
Maximum thrust (lb)	6110	6900	7650
Stroke time (sec)	0.010	0.009	0.008
Final thrust (lb)	4160	4210	4225

Figure 10 exemplifies the thrust-time relationship obtained for the T181 cartridge.

The average thrust for ten firings in the locked-shut position at -65° F was 10,310 lb and at 160° F was 10,540 lb. The maximum thrust obtained for one firing was 11,120 lb; the maximum rate of application of thrust was 2,224,000 lb/sec.

A request for cartridges for tests at Boeing Airplane Company was received prior to the above evaluation. To fulfill this request a tentative charge of 2.8 grams of RAD 3002 with 1.25 grams of A4 granulation black powder was selected. Three firings were conducted at each temperature prior to releasing the cartridges. Average performance data obtained follow.

Temperature	*-65° F*	*70° F*	*160° F*
Time to maximum thrust (sec)	0.008	0.008	0.006
Maximum thrust (lb)	7050	7650	8240
Stroke time (sec)	0.010	0.010	0.009
Final thrust (lb)	4830	5090	4760

Charge development was begun with the cartridge developed for propelling a 40-lb projectile as used with Thruster, T1. These results, in addition to the results obtained with other propellent arrangements, are summarized in the following:

Average Performance Data

Propellant			*Igniter*			
Type	*Lot*	*Mass (gm)*	*Granulation*	*Mass (gm)*	*Max Thrust (lb)*	*Final Thrust (2 in. Travel) (lb)*
M2	RAD 3002	3.2	A4	1.3	8850	6240
M6	Ind 6667S	2.9	A4	1.25	4860	4080
M2	RAD 3004	3.0	A4	1.25	5360	4980
M10	PA 30187	2.5	A4	1.25	8790	5290
M2	RAD 3002	3.0	A4	1.25	8510	6380
M1	Ind 11913	2.75	A4	1.25	4990	4030
M10	PA 30187	2.0	A4	1.25	6890	4260

The above are the average results of two firings at each condition.

(2) Tail Turrent Unlock for the Tail Cone Jettisoning System

A test device which consists of drawing a rod through a die which required a linearly increasing force starting with 3900 pounds at zero travel and increasing to 5800 pounds at one inch of travel while propelling a mass of seven pounds was utilized. A series of firings was conducted with reduced masses of propellant, Lot RAD 3002 (two to three grams). The rod was drawn during all the above firings.

Average Performance Data

Propellant Mass (gm)	*Time to Max Thrust (lb)*	*Max Thrust (lb)*	*Travel Time (sec)*	*Final Thrust (2 in. Travel) (lb)*
3.0	0.006	8360	0.008	4830
2.8	0.006	7920	0.008	5930
2.6	0.006	5890	0.008	4940
2.4	0.007	6050	0.009	4640
2.2	0.006	5820	0.010	4080
2.0	0.006	5130	0.010	3830

All cartridges used in the above firings contained 1.25 grams A4 granulation black powder igniter.

Additional firing tests were conducted utilizing propellant, Lot PA 30187, and 1.25 grams of A4 black powder igniter to ascertain the minimum dynamic force necessary to draw the rod. Summarized below are the averages of two firings at each condition.

Average Performance Data

Propellant Mass (gm)	*Time to Max Thrust (lb)*	*Max Thrust (lb)*	*Travel Time (sec)*	*Final Thrust (2 in. Travel) (lb)*
2.0	0.005	5470	0.008	3500
1.5	0.005	4270	0.008	2790
1.0	0.006	3650	0.010	1730
0.5	0.008	3390	-	-

The rod was not drawn with the 0.5 gram charge. Additional firing tests were conducted with this charge using another die; the rods were drawn. The above data do not indicate the actual performance in view of static tests conducted to verify the drawing force. Results of static tests show that considerably less force was required to draw the rod.

In view of the fact that Cartridge, T181, is being tested at Boeing Aircraft Company and that it appears to be satisfactory, firing tests with the rod and die arrangement have been terminated.

(3) Status of Development

Before standardization of this thruster can be recommended, concurrence from the Air Force concerning further tests for the tail turret unlock system is required. Without this concurrence Frankford Arsenal will be required to develop a more satisfactory method of simulating the conditions of this system. This may be accomplished by a hydraulic buffer or spring arrangement.

In addition, evaluation of the unit under no load, assessment under varying conditions, preparation of Notes on Development Type Materiel, and final report are required.

b. Thruster, Cartridge Actuated, T2E1, and Cartridge, Thruster, T182E1 (Figures 11, 12, and 13)

(1) Upward Seat Ejection System

Thruster, T2E1, which had been developed especially for the downward seat ejector system (Figure 14) and which had to be adapted to the upward seat by a special linkage and damper, will have limited use in this system because Weber Aircraft Corporation is completing development of an actuator operated by Initiator, T5.

(2) Downward Seat Ejection System

Charge development was begun in the Boeing Airplane Company test fixture (Figure 15) in the +g load position. The greatest force would be required of the thruster with this condition.

Several charge arrangements of propellant (Lot PA-E 10257) and damper orifice diameters were used. The igniter used in the above firings was black powder of A4 granulation. Of 18 rounds fired, only two resulted in a complete stroke. Following is a summary of the initial conditions and the results obtained.

Performance Data

No. Rds	Temp (°F)	Orifice Dia (in.)	Propellant Length (in.)	Propellant Dia (in.)	Propellant Mass (gm)	Igniter Mass (gm)	Initial Thrust (lb)	Time Max Thrust (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)
2	70	0.0938	0.55	0.60	4.0	1.0		0.14	2420		
1	70	0.0938	0.60	0.60	4.3	1.5		0.21	3340		
1	70	0.0938	0.65	0.65	5.1			0.19	3730		
1	70	0.0938	0.70	0.70	6.9			0.28	5190		
1	-65	0.1065	0.65	0.65	5.1		1660	0.22	3940		
1	70	0.1065	0.65	0.65	5.1		1850	0.18	5840		
1	160	0.1065	0.65	0.65	5.1		2240	0.15	6720		
1	70	0.1065	0.70	0.70	6.9		1940	0.19			
1	-65	0.1065	0.47	0.75	5.5		1240	0.20	5640		
2	70	0.1065	0.47	0.75	5.5		2210	0.16	7060		
1	160	0.1065	0.47	0.75	5.5		1130	0.12	8210	0.68	2310
2	-65	0.1065	0.65	0.65	5.1		1310	0.25	4700		
1	70	0.1065	0.65	0.65	5.1		1840	0.16	6460	0.77	2190
2	160	0.1065	0.65	0.65	5.1		2390	0.15	7650		

Additional firings were conducted with Propellant, T8, Lot PA-E 11777, 0.715 in. diameter, and 1.5 grams of A4 black powder igniter under various initial conditions with a view to keeping the final velocity below 5 f/s and to assure stroke completion under all conditions. With a damper orifice of 0.1065 inch diameter, thruster stroke was not completed in the cold firing under the +g loading condition. Following is a tabulation of the performance data.

Performance Data

No. Rds	Temp (°F)	Orifice Dia (in.)	Propelled Mass (gm)	Loading	Initial Thrust (lb)	Time Max Thrust (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)	Final Vel (f/s)	Max Vel (f/s)
1	70	0.1065	5.3	Pos		0.17	7290				
1	-65	0.1065	6.1	Pos	1170	0.23	6520				
1	70	0.1065	6.1	Pos	1950	0.14	8270	0.63	2820		
1	160	0.1065	6.1	Pos	1890	0.14	9600	0.63	2920	2.1	4.7
2	-65	0.1065	6.1	Norm	1280	0.22	4970	0.58	2740	2.8	3.7
3	70	0.1065	6.1	Norm	1790	0.15	7220	0.53	3010	3.0	4.3
3	160	0.1065	6.1	Norm	1880	0.15	8380	0.52	3180	2.9	4.4
1	-65	0.1065	6.1	Neg	1380	0.24	4820	0.53	2990	3.6	4.2
1	70	0.1065	6.1	Neg	2820	0.14	8860	0.48	4420	3.6	4.7
1	160	0.1065	6.1	Neg	1470	0.15	8410	0.47	3380	3.6	5.0

To assure stroke completion under all conditions, the damper orifice diameter was increased to 0.120 inch for all subsequent firings. The above firings were conducted without conditioning the damper for the extreme temperature conditions. Subsequent tests were conducted with the dampers temperature conditioned.

The charge tentatively selected for the Cartridge, T182E1, is 6.1 - 0.1 grams of propellant, Lot PA-E 11777 (0.60 in. long and 0.715 in. diameter) and 1.5 grams of A4 granulation black powder igniter. Following is a summary of initial conditions and the results of tests.

Average Performance Data

No. Rds	Temp (°F)	Load (g)	Initial Thrust (lb)	Time to Max Thrust (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)	Final Vel (f/s)	Max Vel (f/s)
2	-65	Pos	1770	0.15	5300	0.59	2390	1.5	5.3
3	70	Pos	2060	0.15	7210	0.50	3340	2.6	6.1
3	160	Pos	2130	0.12	8640	0.47	3150	2.5	6.5
3	-65	Neg	1820	0.17	4950	0.42	3230		
4	70	Neg	2530	0.14	6120	0.38	3200	3.7	4.8
2	160	Neg	1850	0.15	7010	0.39	3460		

In all the above tests the thruster stroke was completed and in none of the tests was the final velocity in excess of 5 f/s.

(3) Status of Development

To complete development, additional tests to substantiate the above tests, firings in the normal g loading position, firing under no load and locked-shut, are required. Following recommendation for standardization, assessment of the thruster under varying conditions, preparation of Notes on Development Type Materiel, and a final report are to be completed.

c. Thruster, Cartridge Actuated, T3, and Cartridge, Thruster, T183E1 (Figures 16, 17, and 18)

(1) Electric Actuator Disconnect and Control Column for Upward Seat Ejection

Charge development was begun with a view to obtaining sufficient thrust to propel a 300-lb mass through a 1.5-inch stroke and by-pass sufficient pressure (by-pass is required in the electric actuator disconnect system only) to operate an Initiator, T5, or Thruster, T2E1, after four feet of flexible hose, MS-28741-4. Experimental firings were conducted with various propellants and propellent arrangements. A summary of the experimental work performed at 70° F follows.

Performance Data

No. Rds	Propellant Type	Propellant Lot	Propellant Mass (gm)	Black Powder Igniter Granu-lation	Black Powder Igniter Mass (gm)	Maximum Thrust (lb)	Maximum Pressure 4-ft Hose (psi)
1	M10	PA-E 6101	2.0	A4	1.0	1610	610
1	M10	PA-E 6119	1.5	"	0.50	1540	250
1	M2	HES 4831.11	1.5	"	0.50	1120	180
1	M2	HES 4831.8	1.4	"	0.50	1460	180
1	H8	5130.16	1.8	"	0.75	1070	510
1	M2	HES 4831.11	1.5	"	1.0	1360	330
1	H8	5130.16	1.8	"	1.0	1100	570
1	H8	5130.12	1.5	"	1.25	940	520
2	H8	5130.4	2.0	"	1.25	660	890
2	H8	5130.12	2.1	"	1.25	1140	1090

Since the last arrangement appeared to yield the best results, additional firing tests were conducted with this charge at the extremes of temperature, locked-shut, and with no load (propelled mass). The following are the averages of two firings at each condition.

Average Performance Data

Propelled Mass (lb)	Temp (°F)	Initial Thrust (lb)	Max Thrust (lb)	Stroke Time (sec)	Time Max Press 4-ft Hose (sec)	Max Press 4-ft Hose (psi)
323	-65	360	1050	0.73	0.07	600
323	160	350	900	0.90	0.10	1110
None	70	230	230	–	–	–
Locked-shut	70	280	1280	–	–	–

No pressure was recorded through the hose under the no load conditions. The piston stop shoulder of the thruster failed to retain the piston. This can be attributed, however, to a defect in the manufacture.

The hose was not temperature conditioned in the above tests. Since this propellent arrangement appeared to produce satisfactory performance, additional tests were conducted to substantiate these results. Following is a summary of results obtained in which the hose, as well as the thruster with cartridge, were temperature conditioned.

Average Performance Data

No. Rds	Propelled Mass (lb)	Temp (°F)	Initial Thrust (lb)	Max Thrust (lb)	Stroke Time (sec)	Time to Max Pressure 4-ft Hose (sec)	Max Pressure 4-ft Hose (psi)
5	323	-65	470	1050	0.106	0.075	910
5	323	70	480	1110	0.085	0.068	980
5	323	160	560	1400	0.074	0.047	1250
10	Locked-shut	-65	480	1870	0.109	–	–
10	Locked-shut	160	510	2160	0.072	–	–
2	None	-65	360	360	0.011	0.635	310
3	None	70	360	360	0.005	0.211	1050

On the basis of these results, this charge (2.1 - 0.1 gm Lot 5130.12, 0.85 in. long and 1.25 gm of A4 black powder igniter) has been tentatively selected for Cartridge, T183E1. Figure 19 shows typical thrust-time and thrust-travel relationships obtained with this cartridge.

(2) Status of Development

In view of the above tests, standardization of this thruster has been recommended. To complete the development, assessment of the thruster under varying conditions, Notes on Development Type Materiel, and a final report are required.

d. Thruster, Cartridge Actuated, T4E1 and Cartridge, Initiator, M38[1] (Figures 20, 21, and 22)

(1) Tail Cone Jack for the Tail Cone Jettisoning System

Cartridge, M38, was selected for use in the Thruster, T4E1. An extensive firing program has been completed. Following is a table summarizing the results obtained from firings at each condition.

[1]This thruster also meets the requirements of the F-85F Airplane, Project No. TSI-15-C8.

Average Performance Data

Propelled Mass (lb)	Temp (°F)	Velocity (f/s)	Peak Thrust (lb) Max	Avg	Min	Thrust at 5.0 in. Travel (lb) Max	Avg	Min
508	-65	10.1	6930	6360	5900	1690	1510	1350
508	70	10.3	6890	6670	6040	1720	1570	1420
508	160	10.6	7230	6930	6620	1890	1680	1560
Locked-shut	-65	–	7500	6780	6010	–	–	–
Locked-shut	160	–	7350	7240	7130	–	–	–

In addition to propelling a 508-lb mass, the thruster shears pins requiring 4000 lb force at zero inch travel and 1000 lb at five inch travel. Figure 23 is a representative thrust-time relationship obtained with Thruster, T4E1, and Cartridge, M38.

(2) Status of Development

Thruster, T4E1, has been standardized as Thruster, Cartridge Actuated, M5. To complete development, additional firings to assess the units under varying conditions, preparation of Notes on Development Type Materiel, and a final report are required.

e. Initiator with Cartridge, Catapult and Canopy Remover, M3, and Cartridge, Initiator, M38 (Figures 24, 25, and 22)

(1) Upward and Downward Seat Ejection and Tail Cone Jettisoning System

In the previous report, Status Report, Dec 1952 to Jan 1953, p 21, tests to determine the feasibility of using Exactor, Canopy Remover, M1, in place of the initiator safety pin and transversal load limitations on the exactor rod were reported. Tests showed that the exactor-initiator arrangement worked satisfactorily when loaded up to 200 lb. However, these tests were considered inconclusive since they did not consider manufacturing tolerances of the units. In view of this, Boeing Airplane Company developed an exactor (Figure 26) capable of operating under considerably larger transverse loading than the 50 lb limitation set for operation with Exactor, M1.

A special project has been proposed to improve Exactor, M1, considering its performance under all tolerance conditions (Project TS1-15-C9).

It should be noted that Initiators, M3, manufactured under the production facility of Frankford Arsenal should not be used with an exactor unless it can be established that they will pass load requirements for safety pin.

Figure 27 is a photograph of a malfunctioned initiator which demonstrates the affect of improper hardening. Specified hardness for the cap is Rc 33-38, for the chamber, Rc 33-38. The malfunctioned cap and chamber were made from WD 4140 alloy steel and hardened to Rc 6 and Rc 16 to 18, respectively. Pitch diameter of the chamber thread was 0.014 inch undersize. Firing was conducted locked-shut at 160° F. The probable locked-shut pressure at this temperature is 10,500 psi.

(2) Status of Development

Firings to assess the units under varying conditions and preparation of Notes on Development Type Materiel are in process. A final report will be prepared after completion of assessment.

f. Initiator, Thruster or Catapult, T5 and Cartridge, Initiator, M38 (Figures 28, 29, and 22)

(1) Upward and Downward Seat Ejector

Initiator, T5, has been standardized as Initiator with Cartridge, M5. Tests conducted to date show that this unit will function satisfactorily in its related systems. Since the volume and cartridge of this unit are the same as for the Initiator, M3, similar locked-shut pressures may be expected.

Locked-shut firings with caps made from WD 4140 alloy steel, hardness Rc 8 (Rc 33 to 38 is recommended) did not result in bursting failure similar to that explained previously under Initiator, M3. However, bulbing or yield failure did occur. It appears that for even single shot firing, lower hardness caps are unsatisfactory.

(2) Status of Development

This unit is in the same state of completion as Initiator, M3 (T4).

g. Delay-Initiator, T13, and Cartridge, Delay-Initiator, T217 (Figures 30, 31, and 32)

(1) Tail Cone Jettisoning System

Delay-Initiator, T13, will be standardized as Delay-Initiator with Cartridge, Thruster, M6. Tests conducted to date show that it will function satisfactorily in this system.

(2) Status of Development

To complete development firings to determine locked-shut pressures, assessment of the unit under varying conditions is required. Preparation of Notes on Development Type Materiel is in process. The final report will follow completion of all development.

h. Evaluation of Firing Mechanisms

(1) Maximum Hose Length

To determine the maximum permissible flexible hose length (MS-28741-4) to assure all fire, the following is contemplated: (1) fire Initiator, M3, into chamber with 0.500 inch diameter firing pin and 0.046 inch diameter copper shear pin for Thrusters, T4, T4E1, and T1E1; (2) fire Initiator, M3, into chamber with 0.500 inch diameter firing pin and 0.032 inch diameter steel shear pin for Thruster, T2E1; (3) fire Initiator, M3, into chamber with 0.375 inch diameter firing pin and 0.046 inch diameter copper shear pin for Initiator, T5, Delay-Initiator, T13, and Thruster, T3E1; and (4) repeat Thruster, T3E1, test using Delay-Initiator, T13.

To date tests have been completed for items (1) and (3). In view of these tests, a 15 foot maximum hose length has been set.

(2) Minimum Hose Length

A minimum length of flexible hose between Initiators, M3 and T5, and their associated unit has been set at four feet. This limitation is due to the rupture strength of flexible hose MS-28741-4. A similar determination for the lower pressure Delay-Initiator, T13, is contemplated.

(3) Maximum Permissible Pressure to Entrance of Gas-fired Units

A need exists for data to determine pressure limitations into the entrance of gas-fired units. Such tests would be conducted by firing Initiator, T4, through flexible hose and stainless steel tubing in lengths less than four feet to determine whether failure of firing chamber would occur.

(4) Study of the Kinetics in Firing Units

To obtain data for future reference and to determine the kinetic conditions existing in the gas-fired mechanisms and their reliability, studies are being conducted to (a) obtain pressure-time data at hose length increments, (b) obtain energy data at hose length increments, and (c) ascertain reliability of present shear pins and effect of increased or decreased diameter on the firing reliability.

(5) Initial Lock Test

Although requirements for initial lock of thrusters do not exist, tensile tests to determine when failure can occur have been completed. Two tests were conducted with a T4E1 thruster in a tensile testing machine and the displacement-load was plotted. Ultimate failure occurred in the housing.

Test 1		Test 2	
Load (lb)	Displacement (in.)	Load (lb)	Displacement (in.)
500	0.058	500	0.040
1000	0.080	1000	0.063
2000	0.110	2000	0.093
3350*	0.163	3250*	0.140

*Ultimate failure

Since Thrusters, T1E1, T2E1, and T3E1, are similarly locked, it can be assumed that similar results would be obtained.

(6) Vibration

Preparations are being made to test all units as requested in letter, Wright Air Development Center, WCLSJ-4, FA 452/1522, 15 April 53, and letter, Wright Air Development Center, WCLSJ-4, ORDBA-LC 5450, 30 June 1953. To date only the Thruster, T4E1, tests referred to in the letter of 15 April 1953 have been completed. Results have been satisfactory.

At present, Frankford Arsenal does not have equipment adequate for performing vibration tests specified for B-52 Airplane escape systems in the letter of 30 June 1953. These requirements have been discussed at Wright Air Development Center on 20 August 1953 between Air Force and Frankford Arsenal representatives. It was agreed that Frankford Arsenal would test all units specified in the general requirements and investigate the feasibility of contracting all other tests. The Air Force agreed to investigate their facilities to determine whether tests can be conducted at Wright Air Development Center and, also, to review the requirements and determine whether the tests are representative of the B-52 Airplane escape system.

It was also agreed that Frankford Arsenal would prepare an estimate of funds required for the complete equipment and facilities necessary to conduct all tests at Frankford Arsenal.

(7) Markings for Identification

The present method of identifying units with metal marking ink has been found unsatisfactory. Information has been obtained of a metal marking which, it is reported, will meet all environmental conditions required by the Air Force. Orders for these markings have been placed for Frankford Arsenal tests.

Note: Delay-Initiator, T13, will be standardized as Delay-Initiator with Cartridge, Thruster, M6.

Cartridge, Delay-Initiator, T217, will be standardized as Cartridge, Delay-Initiator, M46.

Thruster, Cartridge Actuated, T1E1, will be standardized as Thruster with Cartridge, M1.

Thruster, Cartridge Actuated, T2E1, will be standardized as Thruster with Cartridge, M2.

Thruster, Cartridge Actuated, T3E1, will be standardized as Thruster with Cartridge, M3.

Thruster, Cartridge Actuated, T4E1, will be standardized as Thruster with Cartridge, M5.

Cartridge, Thruster, T181, will be standardized as Cartridge, CAD, M42.

Cartridge, Thruster, T182E1, will be standardized as Cartridge, CAD, M43.

Cartridge, Thruster, T183E1, will be standardized as Cartridge, CAD, M44.

Delay Element, T3, used in Cartridge, Thruster, T217, will be standardized as Delay Element, M5.

Initiator, Thruster or Catapult, T5, will be standardized as Initiator with Cartridge, M5.

Cartridge, Initiator, T129, will be standardized as Cartridge, Initiator, M38.

Initiator, Catapult and Canopy Remover, T4, has been standardized as Initiator with Cartridge, Catapult and Canopy Remover, M3.

Exactor, Canopy Remover, T1, has been standardized as Exactor, Canopy Remover, M1.

APPENDIX B

APPENDIX B
(Project TS1-15-C1)

Shear Pin Test

Thruster, Cartridge Actuated, T1E1
(Powder Type: 5280; Powder Charge: 2.8 gm; A4 Igniter: 1.0 gm)

Temp (°F)	Hose Length (ft)	No. Rds	No. Failures
-65	20	10	8
-65	15	10	0
70	20	10	0
-65	18	10	0

Firing Results

Thruster, Cartridge Actuated, T1E1

Round No.	Powder Type	Powder Charge (gm)	A4 Igniter (gm)	Temp (°F)	Time Peak (sec)	Max Thrust (lb)	Final Thrust (lb)	Time End (sec)	Rec Time (sec)
1	RAD 3002	3.2	1.3	70	-	8980	5420		-
2	"	"	"	"	-	9010	5770		0.009
3	"	"	"	"	-	8680	6710		0.008
4	Ind 66675	2.9	1.25	"	-	4710	4080		0.011
5	"	2.8	"	"	-	5000	4080		0.011
6	RAD 3004	3.0	"	"	-	5300	4960		0.012
7	"	"	"	"	-	5420	5000		0.012
10	PA 30187	2.5	"	"	-	8510	5360		-
11	"	"	"	"	-	9060	5210		-
8	RAD 3002	3.0	"	"	-	7120	5240		-
9	"	"	"	"	-	8510	6380		-
14	Ind 11913	2.75	"	"	0.007	4990	3990		0.011
15	"	"	"	"	0.007	4990	4060		0.010
36	PA 30187	2.0	"	"	0.006	6950	4310		0.010
37	"	"	"	"	0.007	6820	4200		0.010

Firing Results (Cont'd)
Thruster, Cartridge Actuated, T1E1 (Cont'd)

Round No.	Powder Type	Powder Charge (gm)	A4 Igniter (gm)	Temp (°F)	Time Peak (sec)	Max Thrust (lb)	Final Thrust (lb)	Time End (sec)	Rec Time (sec)
16	RAD 3002	2.8	1.25	70	0.008	7660	5410		0.011
17	"	"	"	"	0.007	7810	5110		0.009
18	"	"	"	"	0.008	7480	4740		0.011
19	"	"	"	-65	0.008	6780	4730		0.010
20	"	"	"	"	0.007	7200	5110		0.011
21	"	"	"	160	0.006	8290	4770		0.010
22	"	"	"	"	0.006	8060	4460		0.008
23	"	"	"	"	0.006	8370	5050		0.010
25	"	"	"	-65	0.008	7170	4660		0.010
12	RAD 3002	3.0	1.25	70	0.006	9180	4450	0.008	
13	"	"	"	"	0.006	7540	5210	0.008	
26	"	2.8	"	"	0.006	8500	5980	0.008	
27	"	"	"	"	0.006	7330	5880	0.008	
28	"	2.6	"	"	0.005	5820	4960	0.007	
29	"	"	"	"	0.006	5950	4920	0.009	
30	"	2.4	"	"	0.007	6600	4870	0.009	
31	"	"	"	"	0.007	5500	4400	0.009	
32	"	2.2	"	"	0.006	6030	4300	0.010	
33	"	"	"	"	0.006	5610	3850	0.010	
34	"	2.0	"	"	0.007	4640	4030	0.009	
35	"	"	"	"	0.006	5610	3620	0.010	

(Powder Type: PA 30187; A4 Igniter: 1.25 gm)

Round No.	Pdr Chg (gm)	Temp (°F)	Time to Peak (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)
63	2.0	70	0.005	5580	0.007	3650
64	"	"	0.005	5360	0.008	3340
65	1.5	"	0.004	4190	0.008	2450
66	"	"	0.005	4340	0.008	3120
67	1.0	"	0.006	3920	0.011	1710
68	"	"	0.006	3370	0.010	1740
69	0.5	"	0.008	3320		
70	"	"	0.009	3449		
86	1.0	"	0.007	4050	0.012	1660
87	"	"	0.006	3530	0.012	1840

Firing Results (Cont'd)

(Powder Type: PA 30187; A4 Igniter: 1.25 gm) (Cont'd)

Round No.	Pdr Chg (gm)	Temp (°F)	Time to Peak (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)
88	1.0	70	0.006	3570	0.013	1530
89	0.5	"	0.007	2960	0.019	950
90	"	"	0.009	3470	0.020	1250
91	"	"	0.008	3190	0.017	1020
38	2.0	-65	0.008	6030	0.011	4046
39	"	70	0.006	6870	0.009	4190
40	"	"	0.006	7010	0.009	4330
41	"	-65	0.007	6070	0.010	4130
42	"	160	0.005	7730	0.007	4450
53	"	70	0.010	6750	0.014	4250
54	"	"	0.006	6800	0.009	4320
55	"	160	0.005	7590	0.008	4260
56	"	"	0.005	7650	0.008	4320
57	"	-65	0.006	5930	0.010	4120
58	"	70	0.005	6940	0.008	4130
59	"	160	0.006	7590	0.010	4200
60	"	"	0.006	7650	0.010	4130
61	"	-65	0.006	6110	0.010	4260
62	"	"	0.007	6050	0.010	4380

(Powder Type: PA 30187; Powder Charge: 2.0 gm; A4 Igniter: 1.25 gm)

Round No.	Temp (°F)	Time to Peak (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)
93	-65	0.006	6410	0.009	4230
94	70	0.006	7100	0.009	4150
95	"	0.005	6890	0.009	4100
96	"	0.006	6830	0.009	4360
97	-65	0.006	6010	0.009	4100
98	160	0.006	7600	0.008	4180
99	"	0.005	7600	0.008	4230
100	"	0.005	7720	0.008	4160
101	"	0.005	7790	0.008	4300
102	"	0.005	7620	0.008	4020
103	70	0.006	6760	0.009	4100

Firing Results (Cont'd)

(Powder Type: PA 30187; Powder Charge: 2.0 gm; A4 Igniter: 1.25 gm) (Cont'd)

Round No.	Temp (°F)	Time to Peak (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)
104	-65	0.006	6010	0.010	4230
105	"	0.006	5880	0.010	3900
106	"	0.007	6620	0.009	4270
107	70	0.005	7030	0.009	4160

Locked-Shut Firing Results

Thruster, Cartridge Actuated, T1E1
(Powder Type: PA 30187; Powder Charge: 2.0 gm; A4 Igniter: 1.25 gm)

Round No.	Temp (°F)	Time to Peak (sec)	Max Thrust (lb)
43	160	0.005	10030
44	-65	0.008	10110
45	"	0.007	10180
46	"	0.007	10170
47	"	0.006	10170
48	"	0.006	10030
49	160	0.004	10680
50	"	0.005	10350
51	"	0.005	10680
52	"	0.006	10700
76	"	0.005	10560
77	"	0.005	10560
78	-65	0.007	9810
79	"	0.006	10440
80	160	0.005	10900
81	"	0.005	10770
83	-65	0.007	10720
84	"	0.007	10540
85	"	0.006	10430
92	160	0.005	11120

Firing Results (Cont'd)

Thruster, Cartridge Actuated, T2E2
(Powder Type: PA-E 11777; A4 Igniter: 1.5 gm)

Round No.	Pdr Charge (gm)	Temp (°F)	Init Thrust (lb)	Time to Max (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)
43	6.1	70	7150	0.10	16420		
44	6.1	70	1350	0.60	3430		
59	6.1-.1	-65	2130	0.17	13450		
60	6.1-.1	-65	2130	0.18	16810		
61	6.1-.1	-65	1990	0.15	14670		
62	6.1-.1	-65	2780	0.13	13900		
63	6.1-.1	-65	2360	0.19	10830		
64	6.1-.1	160	6720	0.07	12930		
65	6.1-.1	160	2500	0.14	15550		
66	6.1-.1	160	2500	0.14	18020		
67	6.1-.1	160	2360	0.09	11190		
68	6.1-.1	160	2360	0.14	16720		
69	6.1-.1	160	2460	0.15	7840	0.37	3470
70	6.1-.1	160	2060	0.145	7350	0.38	3330
71	6.1-.1	160	2770	0.14	7670	0.37	3820
72	6.1-.1	70	2320	0.15	6200	0.40	3390
73	6.1-.1	70	2340	0.15	6330	0.39	3640

Firing Results (Cont'd)

Round No.	Pdr Type PA-E	Pdr Chg (gm)	A4 Igniter (gm)	Temp (°F)	Init Thrust (lb)	Time to Peak (sec)	Peak Thrust (lb)	Stroke Time (sec)	Thrust End Stroke (lb)	Thrust one sec (lb)	Time, 1500 psi (sec)	Failed to complete stroke by (in.)	g Act	Movies
9	10257	5.2	1.5	70	1760	0.18	6530	0.77	2190	1930	1.51	0	Positive	Yes
10	10257	5.2	1.5	160	2260	0.15	7270	0.93	1680	1610	1.08	5/16	Positive	Yes
11	10257	5.2	1.5	160	2510	0.15	8020	0.90	2190	2060	1.80	1/4	Positive	Yes
12	10257	5.2	1.5	-65	1450	0.23	5060	1.02	1590	1630	1.11	2 1/8	Positive	Yes
13	10257	5.1	1.5	-65	1160	0.26	4330	1.02	1340	1340	0.90	2 11/16	Positive	Yes
14	10257	5.1	1.5	70	1910	0.13	6390	0.87	1610	1510	1.01	3/8	Positive	Yes
15	10257	5.5	1.5	70	2300	0.15	7010	0.85	2050	1860	1.46	7/16	Positive	Yes
16	10257	5.6	1.5	70	2110	0.16	7110	0.82	1860	1660	1.09	7/16	Positive	Yes
17	10257	5.5	1.5	160	1280	0.12	7930	0.68	2310	1820	-	0	Positive	Yes
18	10257	5.5	1.5	160	970	0.11	8480	0.97	1800	1800	1.55	1/2	Positive	Yes
19	10257	5.6	1.5	-65	1240	0.24	5640	0.82	2720	1820	1.28	3/8	Positive	Yes
20	10257	5.5	1.5	-65	-	0.16						1/4	Positive	Yes
21	11777	5.3	1.5	70	-	0.17	7290	0.85	1630	1410	0.90	3/8	Positive	Yes
22	11777	5.3	1.5	70	1960	0.14	5610	0.95	1310	1250	0.75	2 1/4	Positive	Yes
65	10257	5.3	1.0	70	1200	0.28	3750	1.22	900	1170	0.83			
66	10257		1.0	70	960	0.27	3610	1.07	1070	1170	0.84			
67	10257		1.0	70	1250	0.02	1250	1.10	890	-	-			

Firing Results (Cont'd)

Thruster, Cartridge Actuated, T2E2
(Powder Type: PA-E 10257)

Gun and Round No.	Pdr Chg (gm)	A4 Ign (gm)	Temp (°F)	Init Thrust (lb)	Peak Time (sec)	Max Thrust (lb)	Thrust at 1 sec (lb)	Rec Time (sec)	Time 1500 lb (sec)	Final Thrust (lb)
G-5 R-1	4.0	1.0	70		0.13	2720	1360			
G-5 R-2	4.0	1.0	70		0.14	2120	770		0.49	
G-5 R-3	4.3	1.5	70		0.21	3340	1670		1.04	
G-5 R-4	5.1	1.5	70		0.19	3730	1510		1.01	
G-5 R-5	6.9	1.5	70		0.28	5190	1280		0.88	
G-5 R-6	5.1	1.5	70	1850	0.18	5840	1810		1.23	
G-5 R-7	6.9	1.5	70	1940	0.19	7350	2270	0.61	1.85	3030
G-5 R-8	5.1	1.5	160	2240	0.15	6720	1420		0.49	
G-2 R-8	5.0	1.5	70	1830	0.18	5160	1400		0.91	
G-4 R-1	5.1	1.5	-65	2240	0.15	6720	1420		0.49	

Firing Results (Cont'd)

(Powder Type: PA-E 11777; A4 Igniter: 1.5 gm)

			PT Curve					From Movies				
Round No.	Pdr Chg (gm)	Temp (°F)	Init Thrust (lb)	Time to Max (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)	Final Vel (f/s)	Max Vel (f/s)	Time Max Vel (sec)	Max Acc (f/s²)	Time to g Max (sec)
23	6.0	70	1950	0.14	8270	0.63	2820					
24	6.1	-65	1170	0.23	6520							
25	6.0	160	1890	0.14	9600	0.63	2920					
26	6.1	70	1590	0.13	7070	0.53	3130	3.2	4.2	0.175	1.4	0.025
27	6.1	-65	1090	0.22	4810	0.59	2660	2.8	3.7	0.25	1.5	0.025
28	6.1	160	2150	0.15	9170	0.51	3660	3.2	4.6	0.125	1.8	0.025
29	6.1	70	1890	0.16	7590	0.51	2970	3.1	4.3	0.175	2.0	0.025
30	6.1	160	1790	0.18	7520	0.53	2910	3.0	4.2	0.15	2.6	0.025
31	6.1	-65	1470	0.22	5130	0.57	2820	2.7				
32	6.1	160	1690	0.13	8450	0.52	2980	2.7	4.5	0.125	1.5	0.025
33	6.1	-65	(Results N G cartridge seated improperly)									
34	6.1	70	1880	0.17	7010	0.55	2940	2.8				
38	6.1-.1	70	2820	0.14	8860	0.48	4419	3.6	4.7	0.175	2.6	0.025
39	6.1-.1	-65	1380	0.24	4820	0.53	2990	3.6	4.2	0.225	1.7	0.025
40	6.1-.1	160	1470	0.15	8410	0.47	3380	3.6	5.0	0.125	2.3	0.025
41	6.2	160	1670	0.15	7910	0.48	2640					
42	6.2	160	1760	0.15	6860	0.48	2640	3.1	4.9	0.15	2.0	0.025
			(From wire recorder)					3.0	4.8	0.13	3.1	0.010
45	6.2	-65	1710	0.20	6630			1.6	3.9	0.15	1.6	0.025
46	6.2	-65	1840	0.14	7790	0.72	2280	1.1	3.9	0.15	1.4	0.025

Firing Results (Cont'd)

(Powder Type: PA-E 11777; A4 Igniter: 1.5 gm) (Cont'd)

Round No.	Pdr Chg (gm)	Temp (°F)	Init Thrust (lb)	Time to Max (sec)	Max Thrust (lb)	Stroke Time (sec)	Final Thrust (lb)	Final Vel (f/s)	Max Vel (f/s)	Time Max Vel (sec)	Max Accel (f/s^2)	Time to g Max (sec)
47	6.1-.1	-65	1590	0.19	4700	0.63	2280	1.5	5.3	0.12		
48	6.1-.1	-65	1950	0.11	5900	0.55	2490					
49	6.1-.1	160	1870	0.15	6870	0.39	3270					
50	6.1-.1	160	1620	0.15	7150	0.39	3450					
51	6.1	70	2470	0.15	6330	0.39	3250					
52	6.1	70	3250	0.11	6210	0.36	3010	3.2	5.2	0.075	7.5	0.010
53	6.1	70	2470	0.16	6390	0.39	3550	4.0	4.7	0.10	6.7	0.016
54	6.1	70	1910	0.14	5790	0.39	2980	3.8	4.6	0.09	3.9	0.016
56	6.1	-65	1750	0.17	4740	0.42	3220					
57	6.1	-65	1900	0.16	5090	0.42	3300					
58	6.1	-65	1810	0.17	5020	0.42	3170					
74	6.1-.1	70	2040	0.15	7430	0.53	3000	2.5	5.6	0.08	4.8	0.05
75	6.1-.1	70	2110	0.15	7620	0.48	4070	2.7	6.5	0.08	3.5	0.05
76	6.1-.1	70	2040	0.145	6580	0.50	2940	2.5	6.3	0.09	3.6	0.05
77	6.1-.1	160	2470	0.12	9160	0.46	3360	2.7	6.6	0.07	4.4	0.05
78	6.1-.1	160	1850	0.10	8470	0.48	3090	2.2	6.5	0.08	5.3	0.05
79	6.1-.1	160	2060	0.13	8290	0.47	3000	2.6	6.5	0.09	3.5	0.06

Note: Thruster, T2E2, tests are conducted in a special rig supplied by Boeing Airplane Company and with dampers designed and developed by them.

Charge Verification Data

Thruster, Cartridge Actuated, T3E1
(Powder Type: 5130.12; Powder Charge: 2.1; A4 Igniter: 1.25 gm)

Gun and Round No.	Temp (°F)	Init Thrust (lb)	Max Press (psi)	Max Thrust (lb)	Stroke Time (sec)	Press 4 ft Hose (psi)	Time Peak Hose (sec)
G-3							
Rd 1	70	-	1010	190	-	-	-
G-4							
Rd 4	70	-	1360	260	-	-	-
G-1							
Rd 13	70	280	6530	1240	0.090	-	-
G-1							
Rd 14	70	280	6830	1310	0.085	-	-
G-1							
Rd 15	-65	360	3620	690	0.070	680	0.0625
G-3							
Rd 2	-65	-	7340	1400	0.075	510	0.080
G-1							
Rd 11	70	450	6210	1180	0.0975	1060	0.0525
G-1							
Rd 12	70	480	5750	1090	0.075	1120	0.0625
G-5							
Rd 1	160	510	6330	1200	0.075	1470	0.02
G-4							
Rd 3	160	190	3100	590	0.105	750	0.10
G-1							
7	70	430	5090	970		900	
G-1							
8	70	220	3610	690		820	
1	70	510	7580	1440	0.078	920	0.065
3	70	450	9730	1850	0.095		
4	70	450	9910	1880	0.085		
5	70	570	10300	1460	0.100		
6	160	550	6610	1260	0.080	980	0.035
7	-65	670	5740	1090	0.070	830	0.098
8	160	540	7540	1430	0.070	1140	0.043
9	160	530	8010	1520	0.085	960	0.050
10	-65	580	6110	1160	0.080	880	0.090
11	-65	430	4800	910	0.088	590	0.088
12	70	390	2030	340	0.0025	590	0.338
13	70	-	1470	280	0.28	-	-
14	70	330	1710	330	0.0025	130	0.325

Charge Development Data

Thruster, Cartridge Actuated, T3E1
(Propelled Weight, 323 lb)

Gun and Round No.	Powder Type	Powder Chg	A4 Igniter (gm)	Temp (°F)	Init Thrust (lb)	Max Press (psi)	Max Thrust (lb)	Stroke Time (sec)	Press 4 ft Hose (psi)	Time Peak Hose (sec)
G-1	PA-E									
R 1	6101	2.0	1.0	70		8460			610	
G-1	PA-E									
R 2	6114	1.5	0.5	70		8100			250	
G-1	HES									
R 3	4831.11	1.5	0.5	70		5910			180	
G-1	HES									
R 4	4831.8	1.4	0.5	70		7690			180	
G-1	HES									
R 5	5130.16	1.8	0.75	70		5610			510	
G-1	HES									
R 6	4831.11	1.5	1.0	70		7181			330	
G-4	HES									
R 1	5130.16	1.8	1.0	70		5800			570	
G-4	HES									
R 2	5130.12	1.5	1.25	70		4940			520	
G-1	HES									
R 9	5130.4	2.0	1.25	70		4120			860	
G-1	HES									
R 10	5130.4	2.0	1.25	70		2780			910	

Performance Data
Locked-Shut

Thruster, Cartridge Actuated, T3E1
(Powder Type: 5130.12; Powder Charge: 2.1 - 0.1; A4 Igniter: 1.25 gm)

Round No.	*Temp (°F)*	*Init Thrust (lb)*	*Max Press (psi)*	*Max Thrust (lb)*	*Time to Peak Hose (sec)*
15	160	440	9980	1900	0.073
16	160	450	10840	2060	0.075
17	160	530	11120	2110	0.073
18	160	490	9790	1860	0.080
19	160	500	10960	2080	0.073
20	160	550	11630	2210	0.065
21	160	470	9550	1820	0.073
22	160	690	11380	2160	0.063
23	160	520	10460	1990	0.063
24	160	440	10390	1970	0.078
25	-65	380	8880	1690	0.118
26	-65	410	8700	1650	0.123
27	-65	420	8460	1610	0.133
28	-65	460	10440	1980	0.108
29	-65	470	9880	1880	0.113
30	-65	510	9430	1790	0.113
31	-65	650	10630	2020	0.083
32	-65	520	10630	2020	0.090
33	-65	430	9350	1780	0.118
34	-65	560	11840	2250	0.088

323 lb Projected Vertically

(Powder Type: 5130.12; Powder Charge: 2.1 - 0.1; A4 Igniter: 1.25 gm)

Round No.	Temp (°F)	Init Thrust (lb)	Max Press (psi)	Max Thrust (lb)	Time Peak (sec)	Press 4 ft Hose (psi)	Time to Peak Hose (sec)
36	-65	480	5000	950	0.090	1000	0.083
37	-65	560	5460	1040	0.083	990	0.083
38	160	580	7220	1370	0.073	1450	0.033
39	160	570	8030	1530	0.080	1130	0.045
40	160	560	7550	1440	0.070	1230	0.063
41	-65	470	5030	960	0.105	950	0.102
42	-65	420	5560	1060	0.120	890	0.055
43	160	520	6820	1300	0.075	1140	0.058
44	160	560	7040	1340	0.070	1330	0.035
45	-65	420	6550	1250	0.133	740	0.053
46	70	470	6610	1260	0.098	990	0.068
47	70	450	4780	910	0.093	990	0.063
48	70	500	6230	1180	0.070	970	0.068
49	70	490	5430	1030	0.085	1040	0.075
50	70	490	6230	1180	0.080	930	0.065
51	160	310	1620	310	0.005	1170	0.208
52	160	390	2060	390	0.005	870	0.215
53	160	380	2020	380	0.005	1100	0.210
54	-65	450	2370	450	0.013	190	-
55	-65	270	1430	270	0.008	420	0.635

Firing Results

Thruster, Cartridge Actuated, T4E1
(Powder Type: 5280; Powder Charge: 2.8; A4 Igniter: 1.0 gm)

Round No.	Temp (°F)	Vel (f/s)	Time to Peak (sec)	Max Thrust (lb)	Initial Thrust (lb)	Final Thrust (lb)	Time to Max (sec)	Stroke Time (sec)
G-6								
R 15	70	8.8		5900		1480		
1	70	13.8		11500		1910	0.014	0.060
2	70	10.5		6590		1620	0.022	0.072
3	70	10.3		6770		1530	0.020	0.074
4	70			6930		1410	0.020	0.072
5	70	10.0		6690		1400	0.022	0.080
6	70			6770			0.022	
7	70			6810			0.020	
8	70			6890			0.024	
9	70			7640			0.022	
10	70			6970			0.020	
11	160	10.6		6810		1560	0.016	0.074
12	160	10.3		6830		1590	0.018	0.074
13	160	10.4		6710		1560	0.018	0.073
14	160	11.1		7230		1800	0.020	0.070
15	160	10.8		7170		1680	0.016	0.076
16	-65	10.1		6380		1520	0.022	0.076
17	-65	10.0		6040		1420	0.020	0.078
18	-65	9.9		6230		1520	0.028	0.088
19	-65	10.0		6470		1490	0.016	0.074
20	-65	10.2		6470		1520	0.020	0.078
21	70			970		680	0.008	0.016
22	70			6360			0.010	
23	70	10.3	0.020	6560		1520		0.078
24	70	11.2	0.022	6880		1720		0.076
25	70	10.9	0.018	6620		1620		0.076
26	70	10.8	0.020	6830		1620		0.074
27	70	11.1	0.020	6890		1720		0.074
28	160	11.0	0.020	6620		1830		0.078
29	160	10.0	0.018	6830		1690		0.078
30	160	10.4	0.020	7180		1550		0.078
31	-65	9.2	0.020	5980		1690		0.080
32	160	11.4	0.020	7110		1890		0.072
33	160	10.2	0.018	6760		1590		0.078
34	-65	10.5	0.022	6110		1460		0.080
35	-65	10.4	0.024	6190		1520		0.080

Firing Results (Cont'd)

Round No.	Temp (°F)	Vel (f/s)	Time to Peak (sec)	Max Thrust (lb)	Initial Thrust (lb)	Final Thrust (lb)	Time to Max (sec)	Stroke Time (sec)
36	-65	11.0	0.024	6500		1590		0.076
37	-65	9.8	0.022	6170		1350		0.080
46	-65		0.025	6350				
47	-65		0.022	6910				
48	-65		0.022	6550				
49	-65		0.022	6480				
50	-65		0.022	6990				
51	-65		0.022	7000				
52	-65		0.022	7500				
53	-65		0.021	7370				
54	-65		0.024	6010				
55	-65		0.022	6620				
56	160		0.020	7350				
57	160		0.022	7130				
58	160		0.022	7130				
59	160		0.020	7280				
60	160		0.022	7280				
61	160		0.022	7300				
62	160		0.018	7210				
63	160		0.022	7210				
64	160		0.020	7210				
65	160		0.020	7260				
66	160		0.040	3460	1220			
67	160							
68	-65		0.048	2290	1060			
69	160		0.046	2680	840			
70	160		0.038	2720	820			
71	160		0.053	2010	1200			
72	-65		0.054	1580	550			
73	-65		0.062	1470	1020			
74	-65		0.070	2010	870			
75	-65		-	-	-			
76	160		0.026	2750	1120			
77	-65		0.039	-	880			
78	160		0.035	2620	800			
79	160		0.032	2540	700			
80	160		0.036	2300	970			
81	160		0.032	2060	776			
82	-65		-	-	-			

DEVELOPMENT OF ESCAPE SYSTEM FOR B-47 AIRPLANE (Project TS1-15-C6)

Project Engineer: A. K. Oechsle, Capt, USAF
Ballistics Phase: J. L. Helfrich

Authorization: (a) 00 452.1/46, LC 160, 10 Mar 53
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop and test an escape system for the B-47 Airplane.

STATUS: Wright Air Development Center has requested the Ordnance Department to assist in design and development of an escape system for the B-47 Airplane. It has been planned to develop two escape systems for this aircraft, one being an interim system and the other being a final system. These systems have been tentatively laid out on Boeing Airplane Company drawings 5-62039 and 5-62040.

The Boeing Airplane Company has proposed the two systems as illustrated on the above mentioned drawings. A conference was held at Frankford Arsenal to discuss these escape systems. Representatives from Boeing Airplane Company who attended this conference were Mr. R. A. Perkuhn, Mr. R. T. Aikan, Mr. R. R. Douglas and Mr. E. R. O'Brien. At this conference representatives from Frankford Arsenal discussed the proposed escape systems and suggested methods whereby the systems might be improved. The Boeing Airplane Company representatives stated that they would consider rework of the proposed systems in the light of the conference discussions and would prepare tentative layouts of a new proposed system.

No further work has been accomplished on this project.

DEVELOPMENT
OF
A CANOPY JETTISONING SYSTEM
FOR
8-84F AIRPLANE
(Project TS1-15-C8)

Project Engineer: A. K. Oechsle, Capt, USAF
Ballistics Phase: H. A. Sokolowski

Authorization: (a) OO 452.1/20, FA 452/1388, LC 494, 28 Jan 53
(b) OO 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop and test a canopy jettisoning system for the F-84F Airplane.

STATUS: The F-84F Airplane escape system is composed of two separate systems, viz., the canopy jettisoning system and the seat ejection system. Since the seat ejection system has been designed, tested and used in airplane escape systems having similar requirements, only the canopy jettisoning system will be considered in this task. The canopy jettisoning system is composed of Initiator with Cartridge, Catapult and Canopy Remover, M3; two Initiators with Cartridge, M5; Thruster, Cartridge Actuated, T4; and a Republic Aviation Corporation latch actuator. Thruster, T4, is used as a canopy remover in this installation.

Requirements for Thruster, T4, are as follows:

1. Operate satisfactorily with no load on the thruster;

2. Fire locked-shut without mechanical failure;

3. Propel a 325 pound mass upward;

4. Operate satisfactorily over a temperature range of from -65° to 160° F;

5. Operate satisfactorily when initiated by Initiator, M3, over a 15-foot length of Air Force flexible hose (AN 6271-4).

Thruster, T4, was originally designed to use Cartridge, Thruster, T184, which has the same metal parts as Cartridge, Initiator, M38, but which contains a different powder charge. Tests showed that the use of Cartridge, M38, in Thruster, T4, met the requirements for the F-84F Airplane canopy jettisoning system. Standardization of Thruster, T4, as Thruster with Cartridge was recommended as an interim standard for the F-84F Airplane. Frankford Arsenal proceeded with a preliminary design of Thruster, Cartridge Actuated, T5, for the F-84F Airplane as a final design for the system. Thruster, T5, was to have the same performance as Thruster, M4, but would provide no final lock and no by-pass. However, the preliminary design of Thruster, T5, had a final lock but no by-pass. It was decided to stop design on Thruster, T5, and to proceed with the development of Thruster, Cartridge Actuated, T4E1.

Thruster, T4E1, is a modified Thruster, T4, using Cartridge, M38, and having no final lock and no by-pass. Initially, Thruster, T41, made no provision for retaining the end sleeve with the piston, and for this reason was considered undesirable for installation in the F-84F Airplane. Thruster, T4E1, was modified by securing the end sleeve to the piston by means of a bolt. Functional tests will be conducted by Republic Aviation Corporation using the final configuration of Thruster, T4E1, with the cabin pressurized and unpressurized.

Tests of the F-84F Airplane canopy jettisoning system will be conducted by Frankford Arsenal at -65°, +70°, and +160° F to check the reliability of units when used in the proposed system.

Tests have been conducted to ascertain the feasibility of using Cartridge, M38, in Thruster, T4, for ejecting the canopy off the F-84F Airplane. A series of five firings at each temperature has been completed. A tabulation of the average performance data follows.

Temp (°F)	*Max Thrust (lb)*	*Final Thrust (lb)*	*Max Pressure 4-ft Hose (psi)*
-65	6230	1310	750
70	6660	1280	830
160	7510	1470	820

The thruster propelled a 323-lb mass vertically in all the above tests. Figure 33 illustrates the thrust-time and thrust-travel relationships obtained in the above tests.

Tests have been completed to determine whether the thruster would mechanically endure firing in the locked-shut and no load conditions. A summary of the firings at several temperatures follows.

			Average Performance Data	
No. Rds	Firing Condition	Temp (°F)	Maximum Thrust (lb)	Maximum Pressure 4-ft Hose (psi)
2	Locked-shut	-65	8420	-
7	Locked-shut	70	8890	-
2	No load	-65	1210	560
2	No load	160	1110	870

The thrusters were not mechanically deformed during any of the above firings. Several thrusters manufactured by Robert Reiner, Inc., for the Republic Aviation Corporation, were function tested at this arsenal. All the thrusters functioned satisfactory.

Tests were conducted to determine whether Thruster, T4E1, (developed to jettison the tail cone on the B-52 Airplane), would perform satisfactorily under Thruster, T4, test conditions. Five firings completed at -65° F yielded an average peak thrust of 5250 lb and a final thrust of 1660 lb. The thruster propelled a 323-lb mass vertically for a minimum of five inches, a Thruster, T4, requirement.

A series of firings to determine the maximum length of tubing which can be used with Initiator, M38, to function the firing mechanism of Thruster, T4, has been completed. The thruster functioned satisfactorily under each of the following conditions:

No. Rds	Temp (°F)	Hose Length (ft)
2	70	15
3	70	20
5	-65	15

Additional tests are in progress.

APPENDIX C

APPENDIX C
(Project TSI-15-C8)

Shear Pin Test

Thruster, Cartridge Actuated, T4
Using Initiator, M3, with Cartridge, M38

Round No.	*Hose Length (ft)*	*Function*
1	15	Yes
2	15	"
3	15	"
4	15	"
5	15	"
6	15	"
7	15	"
8	20	"
9	20	"
10	20	"

Republic Aviation Corporation Tests

Thruster, Cartridge Actuated, T4
(Powder Type: RAD 459; Powder Charge: 2.5 gm; A4 Igniter: 0.6 gm)

Round No.	*Temp (°F)*	*Pressure 4-ft Tubing (psi)*	*Velocity (ft)*
G-9-1	70	1160	42.9
G-9-2	70	1700	-
G-10-1	-65	1130	44.7
G-11-1	160	1330	44.3
G-11-2	70	-	-
G-8-1	70	-	-

Firing Tests

Thruster, Cartridge Actuated, T4E1
(Powder Type: 5280; Powder Charge: 2.8 gm; A4 Igniter: 1.0 gm)

Round No.	Temp (°F)	Time Peak (sec)	Peak Thrust (lb)	Time to Inch of Stroke (sec)	Final Thrust (lb)	Function
1	-65	0.023	5550	0.060	1880	
2	-65	0.023	5270	0.060	1610	
3	-65	0.025	5200	0.060	1610	
4	-65	0.023	5070	0.060	1610	
5	-65	0.023	5170	0.060	1590	
38	-65					OK
39	-65					OK
40	160					OK
41	160					OK
42	-65					OK
43	-65					OK
44	160					OK
45	160					OK
6	-65					OK
7	-65					OK

Firing Tests

Thruster, Cartridge Actuated, T4
(Powder Type: 5280; Powder Charge: 2.8 gm; A4 Igniter: 1.0 gm)

Round No.	*Temp (°F)*	*Time Peak (sec)*	*Maximum Thrust (lb)*	*Time Stroke (sec)*	*Final Thrust (lb)*	*Time to By-pass Max (sec)*	*Max By-pass (psi)*
1	70	-	-	-	-	-	-
19	70	0.018	6260	0.053	1260	-	-
20	70	0.016	6680	0.053	1180	0.013	820
21	160	0.013	7380	0.043	1400	0.015	860
22	-65	0.018	5780	0.053	1170	0.013	790
23	70	0.018	6630	0.053	1260	0.015	840
24	-65	0.018	6400	0.055	1240	0.015	640
25	-65	0.018	6570	0.053	1390	0.018	810
26	70	0.018	7080	0.053	1420	0.015	840
37	160	0.012	7721	0.058	1330	0.006	670
38	160	0.012	7210	0.065	1660	-	-
39	-65	0.015	5970	0.063	1590	-	-
40	160	0.012	7730	0.046	1500	0.013	920
41	-65	0.018	6440	0.065	1180	-	-

Round No.	*Temp (°F)*	*Initial Thrust (lb)*	*Peak Time (sec)*	*Thrust (lb)*	*Pressure of Tube (psi)*	*Time to Peak By-pass (sec)*
28	70	-	0.015	8020	-	-
29	70	-	0.015	8910	-	-
30	70	-	0.013	9320	-	-
31	70	-	0.015	9470	-	-
32	70	-	-	9320	-	-
33	70	-	0.012	8260	-	-
34	70	-	0.012	8260	-	-
35	-65	-	0.016	8250	-	-
36	-65	-	0.015	8590	-	-
42	160	-	0.021	1050	[illegible]40	-
43	-65	-	0.058	820	710	-
44	160	850	0.043	1160	12[illegible]0	0.040
45	-65	920	-	1600	[illegible]00	0.218

CARTRIDGE ACTUATED EMERGENCY ESCAPE SYSTEM FOR B-66 AND RB-66 AIRPLANES (Project TS1-15-C11)

Project Engineer: A. M. Stott, H. A. Magnus
Ballistics Phase: J. L. Helfrich

Authorization: (a) 00 452.1/2642, FA 452/1349
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop and test an escape system for the B-66 and RB-66 Airplanes.

STATUS: The development of an escape system for the B-66 and RB-66 Airplanes was requested by Wright Field through the Office, Chief of Ordnance, 9 December 1952. As proposed, the system will necessitate two new thrusters for positioning the pilots' and navigator's ejection seats and, possibly, new charges in standardized thrusters to meet the design requirements. Due to the complexity of the system resulting from large hose lengths, numerous fittings and requisite by-passing of gas, it was reasoned that an electrically actuated system, if developed, would be less complicated. It was decided that a parallel development of both an electrically and a gas-actuated system would be conducted until one system showed conclusive progress over the other. During the development it became evident that the gas-actuated system would be completed before the electrical one due to its earlier start and the familiarity with a gas-actuated system. It was decided to continue the development of the electrical system due to its great merit, ease of conversion from a gas system and possible use on other escape systems.

1. Gas-Actuated System

The system as first proposed (Figure 34) utilized

8 - Initiator, Catapult and Canopy Remover, T4
2 - Thruster, Cartridge Actuated, T2
2 - Thruster, Cartridge Actuated, T3E1
1 - Pilot seat positioning thruster stroke 9.5 in.
1 - Navigator seat positioning thruster stroke 13.25 in.
2 - Remover with Cartridge, Aircraft Canopy, M3

To improve the reliability of the system, a great deal of by-passing was eliminated and paralleling of units incorporated wherever possible. It was concluded that standard items could only be used in a few instances.

The system proposed by Frankford Arsenal (Figure 35) utilizes

4 - Initiator, Catapult or Canopy Remover, T8
2 - Remover with Cartridge, Aircraft Canopy, M3
2 - Thruster, Cartridge Actuated, T9 (canopy unlock)
1 - Thruster, Cartridge Actuated, T6 (gun sight)
1 - Thruster, Cartridge Actuated, T7 (seat positioning)
1 - Thruster, Cartridge Actuated, T8 (seat positioning)
1 - Delay-Initiator, T16 (three-second)
1 - Decompression valve actuator

Either of the three air crew members may ready the plane for ejection since after the individual operations the hose lengths are connected to a common fitting. To ready for ejection the gunner actuates an Initiator, T8, which develops propellent gas to actuate Thruster, T6, and then supplies gas to the common fitting. The pilot readies for ejection by firing an Initiator, T8, which develops propellent gas to actuate Thruster, T8, stows the control column and supplies gas to the common fitting. If the navigator desires to ready for ejection, he actuates an Initiator, T8, which develops propellent gas to actuate Thruster, T7, and supplies gas to the common fitting. From this common fitting gas is piped to the decompression actuator which contains no cartridge. This gas operates the actuator and then by-passes to actuate a three-second Delay-Initiator, T16. This three-second delay time accomplished by a powder train, allows for cabin depressurization. Propellent gas from the delay-initiator is delivered to each of two Thrusters, T9, which in turn by-pass their propellent gases to each of two Removers, M3 (canopy).

On 29 and 30 January 1953 meetings were held at Frankford Arsenal for the purpose of reviewing the status of equipment required for the subject system. With this information, Douglas Aircraft Co. planned to complete engineering drawings and releases; US Air Force procurement personnel anticipated making plans for production quantity procurement, and Frankford Arsenal planned to determine military requirements in terms of the actual functioning requirements of each unit to insure that the final product will operate satisfactorily in the aircraft. An Initiator, T17, was added at this time in the line to the control column. The start of the development of this unit was delayed pending receipt of the Douglas control column for development testing. It was concurred in at the 20 April 1953 meeting that an auxiliary initiator should be added to the system to parallel the Delay-Initiator, T16. The delay unit is always to be connected in the line with the auxiliary initiator by means of an automatic pressure valve at altitudes less than 10,000 feet. The plane manufacturer has someone who can design and build the valve. This arrangement removes the delay at low altitudes, permitting the personnel to eject themselves more quickly, since decompression is not necessary at low altitudes.

At the conference on 9 June 1953, a review was made of the hose connections between the Thrusters, T9, and Removers, M3 (canopy), (Figure 36). The removers will be connected directly to the thrusters. This method connects one remover to one thruster with no common or tie-in gas line. This change assures a faster firing of the removers, thereby minimizing the time for the tensile load buildup.

Douglas Aircraft Company has been furnished installation drawings for Initiator, T8; Initiator, T16; Thruster, T6; Thruster, T9; and Remover, M3.

a. Initiator, Catapult or Canopy Remover, T8

The pressure requirements of the system are too severe to be satisfied by Initiator, T4. To meet these requirements Initiator, T8, was developed to supply high pressures and large volumes of gas. The actuating conditions for this initiator are similar to those required for Initiator, T4, due to firing cable configurations. The actuating stroke of the initiator, therefore, has to operate with a minimum travel of 3/4 inch and a 30 lb ± 5 lb force, which limits the amount of energy available to fire the primer with a self-cocking mechanism, this mechanism being desirable from a safety standpoint. Due to the increased charge in the Initiator, T8, cartridge, the No. 26 primer assembled in Initiator, T4, will not perform satisfactorily.

Another low firing energy primer and primer assembly was sought. The No. 28 primer was decided upon and critical run-down tests of an assembly with a firing plug and one without the firing plug were conducted. This limited testing indicates that the assembly without the firing plug presents the lowest energy condition, $\bar{H} + 5\sigma$ equal to 18.5 inch.

To prevent unburned powder from being carried into the hose and possibly clogging or burning in it, a method of filtering the gas was sought. The accepted design combined the best features of both the annulus and peripheral filter. It is expected that this filter investigation will be utilized in the design of the other initiators required for the system.

Testing of the prototype (Figure 37) is in progress and delivery to Frankford Arsenal for testing and evaluation is expected shortly. The tentative performance characteristics of Initiator, T8, are as follows:

Chamber volume, including cartridge volume	2.8 cu in.
Maximum chamber pressure	10,000 psi
Cartridge volume	1.45 cu in.
Pressure at entrance to the following units	1000 psi min
Propellant	9 gm 0.09 web HES, Lot No. 1 or 2
Igniter	1 gm A4 black powder

b. Thrusters, Cartridge Actuated, T7 and T8 (Seat Positioning)

The original performance characteristics of these units were set forth in a letter from Office, Chief of Ordnance, to Frankford Arsenal (OO.452.1/2642; FA 452/349). The stroke of Thruster, T7, was defined as 13.25 in. and of Thruster, T8, as 9.5 in., while the performance characteristics were defined as:

Maximum acceleration	5 g
Maximum rate of acceleration	60 g/sec
Maximum initial thrust	900 lb
Maximum final thrust	300 lb

The performance characteristics were changed at the meetings of 29 and 30 January. The stroke for Thruster, T7, was defined as 9 9/16 in. ± 1/16 in. with up to 8 inches of free run due to seat adjustment. The stroke for Thruster, T8, was defined as 13 5/16 in. ± 1/16 in. with up to 12 in. of free run due to seat adjustment. The other performance characteristics became:

Maximum acceleration	-1 1/2 g + 1 g to 2 1/2 g min to 5 g max
Initial and final thrust	900 to 1700 lb
Propelled mass equivalent	350 to 525 lb
Initial lock strength	500 lb tensile

The final velocity which the units may develop was not known pending information set forth by the Aero Medical Laboratory. This velocity later became set as 6 to 8 f/s with an absolute maximum of 10 f/s.

Limited velocities as set forth suggested the use of buffers. The use of buffers with a propellent charge may complicate the ballistic development; therefore, to further the progress of the project it was concluded at the 9 June meeting that a parallel development should be carried out. This parallel development will consist of a unit without any buffer and a unit with a variable buffer. Both designs incorporate a chamber to burn the propellant and transmit the gas through an orifice to the piston chamber. This arrangement effects a relatively constant pressure during burning and changes of initial volume will not affect the burning of the charge. The changing initial volumes are obtained by the pre-positioning by the aircraft's personnel as the thruster pistons are connected to move with the seats. In one design the propellent charge is calculated to be consumed before the end of the stroke and the residual gas to complete the operation under low pressures, in order to restrict the velocity.

The variable buffer design is to burn its propellant throughout the stroke with a hydraulic buffer dampening the motion the last few inches of stroke. The length of buffer stroke is directly proportional to the pre-ejection position of the thruster piston, the maximum buffer distance being some three inches, the minimum approximately 1/4 inch.

The ballistic requirements for the units are:

Initial volume	Thruster, T8, 17.65 cu in.; Thruster, T7, 17.65 cu in.
Final volume	Thruster, T8, 34.45 cu in.; Thruster, T7, 41.51 cu in.
Orifice diameter	0.1 in.
Propellant	7 to 10 gm of either 0.08 web H8 propellant or 0.10 web ABL 1803 propellant
Igniter	2 gm of A4 black powder
Primer	No. 28

c. Thruster, Cartridge Actuated, T6 (Gun Sight)

At the meetings of 29 and 30 January 1953 it was agreed that a thruster other than Thruster, T3, should be used to position the gun sight since Thruster, T3, could not satisfy the design requirements and no by-passing of gas is necessary. The performance characteristics were established for Thruster, T6, as follows:

Stroke	1 1/2 inch with 3/8 inch free travel possible
Initial and final thrust	700 to 1200 pounds
Propelled mass equivalent	500 pounds
Initial locked strength	500 pounds tensile

and mounting dimensions similar to those for Thruster, T3.

Douglas Aircraft changed the amount of free run to 3/16 inch during the 20 April meeting. A change of the positioning requirements enabled the use of a developed charge, T183E1, to be used. The use of this charge required a slight change of the thruster's initial and final volume requirements. A unit had been designed by this time, but this change was slight.

The design of this unit (Figure 38a) has been completed and testing is in progress. Thrust requirements are shown on the load curve (Figure 38b); tentative charge and new requirements are listed as follows:

Propelled mass equivalent	60 lb
Maximum pressure	10,000 psi
Initial volume	0.865 cu in.
Final volume	1.160 cu in.
Piston area	0.196 sq in.
Cartridge	T183E1
Cartridge volume	0.195 cu in.
Propellant	H8 PXS 1279, Lot No. 5130.12
Propellant web	0.134 in., single perf
Propellant configuration	0.094 in. ID, 0.301 in. OD
Igniter	1.2 gm A4 black powder
Primer	Caliber .30, No. 26, Specification 50-1-38

d. Decompression Actuator

The meetings of 29 and 30 January 1953 established that this part would contain no cartridge, being powered by the propellent gas from Initiator, T8. Fabrication and supply of this unit was made a Douglas Aircraft Corporation responsibility. Several units and detail drawings have been sent to this arsenal to enable the development testing of Initiator, T8.

Douglas Aircraft Corporation stated at the 9 June 1953 meeting that they had subcontracted the design to Aerotec Corporation. To aid in the further design of the unit, an estimated pressure in the vicinity of this unit has been requested from Frankford Arsenal. This pressure was estimated as 2000 psi.

e. Delay-Initiator, T16

It was decided at the meetings, 29 and 30 January 1953, that the time delay of three seconds, necessary to allow for decompression of the cabin, would be accomplished by a standard delay element loaded with a three-second powder train assembled with the charge.

Testing of this unit is being conducted with a cartridge assembled without the delay elements but presenting the same charge volume. This is done to save the cost of the delay units and expedite the testing by eliminating the loading and fabrication time required for the delay units.

The performance characteristics of Initiator, T16 (Figure 39), have been established as

Pressure at exit of unit	6000 psi
Chamber volume	3.5 cu in.
Cartridge	T231
Cartridge volume	0.318 cu in.
Propellant	M2, JAN-P-323, RAD Lot No. 477
Propellant web	0.04
Propellant configuration	7 perforations, 0.024 in. dia
Propellant grain length	0.512 in.
Propellant grain diameter	0.219 in.
Propellant weight	4 gm
Igniter	1 gm A4 black powder
Primer	Type M2, MIL-P-2044

f. Initiator, Control Column, T17 (Auxiliary)

This initiator was incorporated in the system during the 20 April 1953 meeting. It was decided that since it paralleled Initiator, T16, their performance characteristics would be identical, with the exception of the time delay.

At the 9 June 1953 meeting it was concluded that, since the appearance of this auxiliary initiator is similar to that of Initiator, T16, the Initiator, T17, units should have different bolt locations in addition to different markings to avoid possible installation errors.

The development of this unit is dependent upon the charge development being conducted for Initiator, T16.

g. Thruster, Cartridge Actuated, T9 (Canopy Unlock)

At the meetings of 29 and 30 January 1953 it was agreed that a thruster other than Thruster, T2E2, should be used to unlock the canopy since this unit could not satisfy the design requirements. The performance characteristics were established for Thruster, T9, as follows:

Stroke	5.7 inches
Initial thrust	4500 lb
Equivalent propelled mass	20 lb

By-pass of gas required and the installation parameters should be identical with those for Thruster, T2E2.

Douglas Aircraft Corporation reworked their canopy locking mechanism which resulted in lower thrust requirements (Figure 40).

The change of hose length after by-passing, established during the 9 June 1953 meeting, further changed the design requirements and caused another engineering and design study to be made. Established performance characteristics of Thruster, T9 (Figure 41), are:

Propelled mass equivalent	20 lb
By-pass pressure at end of a single length (6 ft) of flexible hose	1500 psi
Maximum pressure	12,500 psi
Initial volume	5.5 cu in.
Final volume	12.6 cu in.
Piston area	1.23 sq in.
Cartridge volume	1.45 cu in.
Propellant	M2 JAN-P-323, Lot No. RAD 477
Propellant configuration	7 perforations, 0.024 in. diameter
Propellant grain length	0.512 in.
Propellant grain diameter	0.219 in.
Propellant weight	3 gm
Igniter	1 gm A4 black powder, JAN-P-323
Primer	Caliber .50 No. 28 JAN-P-749

h. Remover with Cartridge, Aircraft Canopy, M3

The large area of the canopy imposes a loading on the removers due to pressure differential and aerodynamic lift. As it was felt that this loading might hinder the operation of the remover firing mechanism, studies were made to determine what load the removers might take without jamming the latches. During this study it was found that the remover head will fail at approximately 12,000 pounds. If the latches could function under this loading, the possibility of a jam-up would be avoided. A test was conducted to determine what loading would jam the latches. It was found that a tensile load in excess of 2500 pounds would prevent functioning; therefore, another solution was attempted. To aid in alleviating this possible jam-up, a change of hose length was suggested at the June meeting. This change insured a faster firing of the units.

On 26 June 1953 Wright Field requested, through Office, Chief of Ordnance, the development of a new remover. This remover should be identical to the present Remover, M3, except for the internal locking mechanism. The modified remover should contain an internal locking mechanism which will allow the inner and outer remover tubes to separate under tension loads in excess of 1000 pounds. If this cannot be accomplished without greatly altering the present design of Remover, M3, the present latches will be deleted from this unit and an external lock provided to prevent the remover from telescoping during shipment and storage.

2. Electrically Actuated Systems

a. Piezo Crystals

After investigation, it has been decided that piezo crystals cannot meet the energy requirements of the present electric primers. This study was discontinued in the interest of safety, reliability, and simplicity.

b. Electromagnetic

Satisfactory results have been obtained. Designs are being studied to reduce the size and configuration of initiators as compared to units designed for gas operation. Conversion to this type system is not as simple as in the case of battery operated units; therefore, the battery system is to be developed first.

c. Batteries

Plug-in batteries packaged in a specially designed container are proposed. The container is to be hermetically sealed with small current consuming heater strips enclosed. These heater strips will be permanently connected to the main battery, thereby keeping the battery pack at a nearly constant temperature and prolonging its life span. The internal wiring of the hermetically sealed container consists of a 2-microfarad condenser connected in parallel with each battery. These high quality condensers have a long build-up period but very small leakage. A hookup of this type obtains the optimum life span from the battery as it only has to replenish the small leakage of the condenser.

Discussions were held with personnel of the Squier Signal Laboratory, Fort Monmouth, New Jersey, concerning developments in the field of batteries. Information was obtained about a new battery developed by the Signal Corps and Olin Industries. The principal features of this battery are expected to be small size, ruggedness, excellent temperature characteristics, and a shelf life of five years. This battery is still in the development stage. Frankford Arsenal has been placed on the distribution list for progress reports on this development and will receive sample quantities of the batteries when they become available.

d. Primers

Work on the first phase of developing a modified M52A3 Primer with a reduced charge of 0.6 grains of X-878 priming mixture is in progress. Approximately 200 of these primers have been loaded on a laboratory scale and the sensitivity has been tentatively established, obtaining an all-fire voltage of approximately 75 volts from a 2-microfarad condenser. Since the firing circuit from which these primers are to be fired can be as low as 70 volts, efforts will be made to increase the sensitivity. Fifty of these primers have been submitted for ballistic evaluation in Remover, M3 containing Cartridge, Remover, M31A1. The results of these firings will determine if any adjustment in the primer pellet weight is required. Additional quantities of components for this primer have been ordered. A larger quantity will then be made by machine, tooling for which is now available.

Small quantities of components for the intermediate size primer have been received. This primer is designed for use in those cartridges in which the modified M52A3 Primer is too large.

e. Circuits

Two types of circuits were studied, the one containing nine batteries being the most promising. This circuit (Figure 42) consists of gun sight retraction thruster, navigator seat positioning thruster, decompression actuator, two canopy pin release thrusters, two removers, control column initiator, six DPST switches, one TPST switch, one barometric switch, nine batteries with matching condensers. The firing sequence may be started by the manual operation of either the switch controlling the gun sight retraction thruster, the navigator seat positioning thruster or the pilot seat positioning thruster and the associated control column stowage. While the unit is positioning, a decompression actuator dumps the cabin pressure to equalize it. When the pressure has reached a safe ejection value, the canopy pin release thrusters are automatically fired. Complete removal of the canopy pins activates the remover firing switches and the canopy is removed from the plane. In the event of a ground emergency, an external switch has been provided for operating the canopy pin release thrusters. The release of the canopy pins fires the removers, removing the canopy. Checking of the batteries is to be accomplished by a rotary switch and neon bulb. Failure of the neon bulb to light at the switch position dictates the replacement of the battery-condenser unit. At the points of installation, low voltage current meters (laboratory type) will be used to check out the complete system. One of the Douglas Aircraft Corporation contractors will look into the problem of the barometric switch needed for this circuit.

A laboratory model of the battery pack was assembled and potted. The potting compound cures at approximately room temperature, thereby producing no adverse effects on either the batteries or condensers. In connection with this unit a hermetically sealed thermostatically controlled heater is on order. This heating unit will be capable of maintaining the battery pack at +50° to +70° F when the ambient temperature is -65° F. Power for the heater will be obtained from the 24 VDC plane supply. Delivery of this unit is expected during October 1953.

A model of another system using a single 135V battery with nine current limiting resistors and nine condensers, one condenser being in series with each resistor, is presently undergoing tests.

Investigations on the method of actuating the switches required in the circuit and investigation of a means of assembling the electric cartridges are currently being conducted.

ESCAPE SYSTEM TEST, XB-57 AIRPLANE
(Project TSI-15-C34)

Project Engineer: J. L. Helfrich
Mechanical Engineering Phase: A. K. Oechsle, Capt, USAF

Authorization: (a) FA 334/6231-1, 11 May 53, 1st Ind WADC to FA
(b) 00 452.1/89, FA 452/1558, 30 June 53
(c) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To evaluate the proposed escape system for the XB-57 Airplane to determine whether the units chosen will function satisfactorily in the integrated system.

STATUS: The Memorandum for Record and Approval of Expenditures has been prepared, outlining experimental procedures and quantities of material deemed necessary to complete the evaluation.

DEVELOPMENT OF THE ESCAPE SYSTEMS FOR THE CONSOLIDATED-VULTEE AIRCRAFT CORPORATION AIRPLANES F-102A AND TF-102
(Project TSI-15-C37)

Project Engineer: A. K. Oechsle, Capt, USAF
Ballistics Phase: H. A. Sokolowski

Authorization: (a) 00 452-1/89, FA 452/1558, LC 5907, 30 June 53
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop and test an escape system for the F-102A and TF-102 Airplanes.

STATUS: At a conference held at Wright-Patterson Air Force Base on 26 March 1953, the escape system proposed by the Consolidated-Vultee Aircraft Corporation was discussed. The requirements for canopy jettisoning are as follows for the F-102A Airplane:

Total number of latches	8
Number of latches on each side of canopy	4
Force required to operate each latch	
Cabin pressurized	32 pounds
Cabin unpressurized	22 pounds
Total maximum force required (65 per cent travel)	272 pounds
Latches released by operation of teleflex cable	all
Canopy weight	170 pounds
Canopy effective mass	1530 pounds
Thruster stroke required to operate linkage	2 inches
Maximum advantage or disadvantage of linkage mechanism to apply force to teleflex cable	unknown

It was anticipated that Thruster, Cartridge Actuated, T1E1, would be used to actuate the unlatching mechanism although the thrust performance of this unit was believed far in excess of the requirement. Thruster, Cartridge Actuated, T3E1, has a thrust performance nearer that required for this operation, although the stroke is only 1½ inches plus overtravel. A modified version of this unit, using the same cartridge and having the required stroke, would probably be more adaptable to this system. Since the catapults required for this system have been tested in other systems having similar requirements, testing of this portion of the escape system will not be required.

During a visit to Consolidated-Vultee Aircraft Corporation, San Diego, California, a representative of the Pitman-Dunn Laboratories witnessed tests of Remover with Cartridge, Aircraft Canopy, M1A1, on the canopy test jig for the F-102A Airplane. The results of these tests follow.

The test was conducted at ambient temperature (+78° F) with a sponge rubber disc between contact surface of remover and canopy to provide 3/3 inch free travel. The simulated canopy hurled free of the test jig approximately 15 feet, making a half turn. When the canopy is open it normally pivots, but since it is opened wider it shears the mounting pins which have been designed with this in mind. The sponge rubber disc giving 3/8 inch free travel appeared to have little effect on performance. Free travel is desired for actuating a switch prior to ejection.

The above test was repeated except that the sponge rubber disc was replaced by an aluminum disc. Results were comparable. The canopy was successfully removed and thrown approximately 15 feet.

At ambient temperature (+78° F) the remover was fired locked-shut. The remover remained intact.

After an overnight cold soak at -65° F the remover was fired using the aluminum disc. Performance was comparable with the vaults at +78° F.

After soaking the remover at +160° F for several hours it was fired. The performance was noticeably greater as was expected in that the simulated canopy was hurled approximately 20 feet.

Because the previous locked-shut test gave a force reading lower than that during other tests, this test was repeated. The results were comparable to the above mentioned locked-shut test. The instrumentation was to be checked to determine whether the method of restraint affected the results sufficiently to cause a lower force value to be recorded for the locked-shut tests as compared to that recorded for the other tests.

The preliminary tests described above indicate that satisfactory canopy removal is possible on the F-102A Airplane with one Remover, M1A1.

On 18 June 1953, Wright Air Development Center requested the Office, Chief of Ordnance, Department of the Army, to direct Frankford Arsenal to develop and test the F-102A Airplane escape system and to furnish service test items. On 30 June 1953, Office, Chief of Ordnance, requested Frankford Arsenal to proceed in compliance with Wright Air Development Center letter to Office, Chief of Ordnance, dated 18 June 1953.

DEVELOPMENT
OF
ESCAPE SYSTEM
FOR
LOCKHEED AIRCRAFT CORPORATION AIRPLANES F-94C AND T-33
(Project TSI-15-C38)

Project Engineer: A. K. Oechsle, Capt, USAF
Ballistics Phase: J. L. Helfrich

Authorization: (a) Ltr WADC to OCO, WCLSJ-4, FA LC 5643, 3 Jul 53
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop and test an escape system for the F-94C and T-33 Airplanes.

STATUS: On 20 March 1953 a conference was held at Frankford Arsenal to discuss the F-94C and T-33 Airplane escape systems. It was determined that (1) Wright Air Development Center would define the military characteristics; (2) Frankford Arsenal would design and develop a canopy unlatching thruster having a three-inch stroke similar in performance to the present Thruster, Cartridge Actuated, T4E1; and (3) Frankford Arsenal would determine the reliability of the units when used in the proposed F-94C and T-33 aircraft canopy jettisoning systems. It was indicated that the F-94C and T-33 aircraft canopy jettisoning systems would probably have the same requirements and, therefore, would be considered as a single task. Only the canopy jettisoning portion of the escape systems will be considered in this task, since the seat ejection catapults have been tested, developed, and in use for some time.

During a visit to Wright-Patterson Air Force Base, Ohio, on 11 and 12 June 1953, the Special Projects Branch, Aircraft Laboratory, Wright Air Development Center, stated that the Thruster, T4E1, would probably fill the requirements for the F-94C and T-33 aircraft canopy unlatch thruster since redesign of the latch mechanism would permit over travel. It was also stated that Lockheed Aircraft Corporation would perform all the testing required provided all units to be used had been standardized. However, examination of the system proposed by Lockheed Aircraft Corporation indicates that a larger initiator, possibly Initiator, Catapult or Canopy Remover, T8, may be required. Since Initiator, T8, has not been standardized, Frankford Arsenal may be required to test the subject system. For this reason the F-94C and T-33 aircraft escape systems remain as a tentative job.

DEVELOPMENT
OF
ESCAPE SYSTEM
FOR
BOEING AIRPLANE COMPANY AIRPLANE RB-52
(Project TSI-15-C39)

Project Engineer: G. Meranshian
Ballistics Phase: H. A. Sokolowski

Authorization: (a) 00 452.1/1185, FA 452/966-2, LC 78283, 8 Nov 51
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop and test an escape system for the RB-52 Airplane.

STATUS: The RB-52 Airplane is a reconnaissance version of the B-52 Airplane and requires an escape system in addition to the system presently under development as Project TS1-15-C1. Funds and authorization for this project have been provided with the system for the B-52 Airplane. However, additional funds may be required to complete this program. An estimate of these additional funds will be made in a Memorandum for Record and Approval of Expenditure.

It is expected that Frankford Arsenal will meet the 1 July 1954 delivery commitment of units to Boeing Aircraft Company for system tests.

Development of only one system under this project is required. Figure 43 is a schematic drawing of this system which is for downward seat ejection. This system will require the following units:

Initiator with Cartridge, Catapult and Canopy Remover, M3 (developed)

Initiator, Thruster or Catapult, M5 (developed)

Delay-Initiator, T16 (under development)

Exactor, Canopy Remover, M1 (developed, may be replaced by Boeing Airplane Company exactor)

Thruster, Cartridge Actuated, T1E1 (under development)

The general military requirements for this system are similar to that of the B-52 Airplane system. Specific military requirements for each unit have also been set. Delay-Initiator, T16, contains a 3 1/2 second delay cartridge. This unit is being developed specifically for the Douglas RB-66 Airplane. Tests will be conducted to determine its usability in the RB-52 Airplane system.

DEVELOPMENT OF ESCAPE SYSTEM
FOR
F-86H AIRPLANE
(Project TSI-15-C45)

Project Engineer: A. K. Oechsle, Capt, USAF

Authorization: 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To develop and test an escape system for the F-86H Airplane.

STATUS: The F-86H Airplane will require standardized items which, for the most part, have been tested in systems that are similar and will not require testing. However, it is desired to initiate the canopy jettisoning system by either of two Initiators with Cartridge, Catapult and Canopy Remover, M3, fired by the actuation of a separate trigger for each. The testing of the F-86H Airplane canopy jettisoning system will consist of tests on the system by firing each initiator separately to check the system reliability and operation of the check valves required for the system, and both Initiators, M3, fired simultaneously to determine the effect on the system.

The F-86H Airplane escape system has remained a tentative job since Wright Air Development Center has not requested the Department of the Army, Ordnance Corps, to proceed with this work.

SECTION I

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

AIRCRAFT LABORATORY
(WCLSJ-4)

F. Miscellaneous

REMOTE ACTUATED HARNESS SAFETY RELEASE
(Project TS1-15-C18)

Project Engineer: J. L. Helfrich
Mechanical Engineering Phase: S. J. Kent

Authorization: CSO 52-896-Ord, 17 Jan 52

OBJECT: To design, develop, fabricate, and test remote actuated release systems for safety harnesses.

STATUS: Two systems were developed and tested. However, final development of this system has been suspended pending investigation of an alternate design. Wright Air Development Center has requested suspension and will advise Frankford Arsenal of action taken and of any future developments pertaining to the harness system.

CALIBRATION, PROCUREMENT, AND CONSTRUCTION OF INSTRUMENTATION FOR USE IN TESTS OF CARTRIDGE ACTUATED DEVICES
(Project TSI-15-C28)

Project Engineer: J. L. Helfrich
Mechanical Engineering Phase: R. Markgraf

Authorization: 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To insure that the experimental data for the Cartridge Actuated Devices program are obtained with the most accurate, most precise, and most reliable instrumentation currently available, and to develop and construct needed instrumentation which is not commercially available.

STATUS: The Memorandum for Record and Approval of Expenditures, indicating the scope of the program and requesting funds, has been approved. A compilation of instrumentation developments accomplished before the initiation of this project is in progress and will be covered in the next issue of this status report.

DEVELOPMENT
OF
CARTRIDGE, REMOVER, T180
(Project TS1-15-C32)

Project Engineer: H. A. Sokolowski
Mechanical Engineering Phase: J. J. Gricius

Authorization: Verbal (Confirmation has been requested)

OBJECT: To develop a cartridge for the Bell Aircraft Corporation X-2 Airplane cabin jettison system.

STATUS: Bell Aircraft Corporation, with the aid of Frankford Arsenal, has developed a cabin jettison system for the X-2 Airplane. Considerable difficulty has been encountered with functioning at the elevated temperature. Frankford Arsenal has reports on file covering the twenty tests conducted at Bell Aircraft Corporation, and has been requested to estimate on continuing the development of Cartridge, Remover, T180, at Frankford Arsenal utilizing sets of the cabin jettison system supplied by Bell Aircraft Corporation.

VIBRATION TESTS ON CARTRIDGE ACTUATED DEVICES
(Project TSI-15-C33)

Project Engineer: R. Gelman
Mechanical Engineering Phase: J. J. Gricius

Authorization: (a) Ltr, WADC, FA 452/1522, 15 May 53
(b) 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To study the effects of vibration on cartridge actuated devices.

STATUS: A Memorandum for Record and Approval of Expenditures has been written in which it is proposed that subject mechanisms be vibrated in accordance with above letter of authorization.

PHYSICS OF CARTRIDGE ACTUATED DEVICES (PART I)
(Project TSI-15-C44)

Project Engineer: S. G. Hughes
Mechanical Engineering Phase: C. J. King

Authorization: By direction of Dr. W. J. Kroeger within the scope of Project TS1-15 and appropriate RADs

OBJECT: To study interior ballistic theory of cartridge actuated devices.

STATUS: A Memorandum for Record and Approval of Expenditures has been written in which it is proposed that a study of theoretical interior ballistics be made on the physics of cartridge actuated mechanisms.

DYNAMICS OF CARTRIDGE ACTUATED DEVICES
(Project TS1-15-C48)

Project Engineer: R. Gelman
Mechanical Engineering Phase: C. M. King

Authorization: By direction of Dr. W. J. Kroeger within the scope of Proj TS1-15 and appropriate RADs. Approved 26 Aug 53

OBJECT: To study the dynamics of cartridge actuated devices.

STATUS: A Memorandum for Record and Approval of Expenditures has been written in which it is proposed that a study be made of the mechanics of the dynamics of cartridge actuated devices with particular attention to vibrational response.

DESCRIPTION OF MANUFACTURE
OF
CARTRIDGES FOR PROPELLENT ACTUATED DEVICES
(Project TS1-15-C49)

Project Engineer: R. T. Fillman
Ballistics Phase: M. Kowalchick

Authorization: 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To prepare reports on methods of manufacture of cartridges.

STATUS: Up to the present time more than 40 different cartridges for various propellent actuated devices have been designed, developed and manufactured in pilot lots by the Pitman-Dunn Laboratories. During the development stage, cartridge cases are manufactured exclusively within the Laboratory. When the cartridges are found to be satisfactory or after they are standardized, the responsibility for the production of them is assigned to other arsenal divisions and, possibly, to private contractors. Development information, such as tool drawings and fabricating procedures, particularly concerning the cases, is helpful to these production facilities and is usually requested by them when they are called upon to manufacture these items. Most of this information is not readily available in a central location. To correct this condition, a program is being initiated to accomplish the following work:

a. Prepare drawings of all tools used in the manufacture of cartridge cases.

b. Prepare, for each cartridge case, a drawing describing the sequence of operations.

c. Write reports covering the method of manufacture for each cartridge. Up to the present time most of the data necessary for accomplishing the above for approximately 23 of the cartridge cases have been clarified and compiled. A form for the sequence-of-operations drawing has been proposed and approved, and will be followed for each cartridge case.

BASIC STUDIES
FOR
BALLISTIC DEVELOPMENT OF CARTRIDGE ACTUATED DEVICES
(Project TSI-15-C72)

Project Engineer: P. W. Sieck, Pfc
Mechanical Engineering Phase: C. M. King

Authorization: 00 113/1287, FA 121/16620, 13 Oct 53

OBJECT: To provide basic studies for ballistic development of cartridge actuated devices.

STATUS: A theoretical investigation has been made of the characteristics of high-low pressure (HLP) cartridge actuated devices. In such a device the propellant is burned at high pressure in a rocket chamber, then vented through a nozzle into a low pressure chamber where it acts on a piston.

The HLP gun has been theoretically studied by Corner;[1] but the wide discrepancies between conditions in a gun and in a cartridge-actuated device both invalidate some of his approximations and make possible other simplifying assumptions.

Among the theoretical advantages of an HLP cartridge-actuated device are: (1) more regular burning of propellant (due to higher pressure at which burning takes place), (2) independence of propellant burning on load, and (3) the possibility of separately adjusting the peak pressure and the initial rate of rise of pressure without change of propellant.

A design chart has been drawn on which the two design parameters of the system can be immediately found from the desired peak pressure and initial rate of rise of pressure. The two parameters thus found give the pressure-time, velocity-time, and travel-time curves from a set of universal curves.

This work is now being prepared for publication as a report.

[1]Corner, J., Franklin Inst. Journal, 246 (1948), 233

BASIC STUDIES FOR MECHANICAL DEVELOPMENT OF CARTRIDGE ACTUATED DEVICES
(Project TSI-15-C73)

Project Engineer: F. J. Shinaly
Ballistics Phase: S. D. Rolle

Authorization: OO 113/1287, FA 121/16620, 13 Oct 53

OBJECT: The purpose of this project is to provide for basic mechanical studies and to support end item development of cartridge actuated devices.

STATUS: No work was done on this project during the period 31 January to 1 July 1953, but an outline of the scope of the proposed work follows.

A study of the ballistic relationships for a catapult, as they relate to its mechanical design, is contemplated. This knowledge would enable designers to build catapults with a more theoretical approach to the design parameters. This study could be extended to cover thrusters and removers.

The theory of operation of a buffer with hydraulic and/or viscous dampening will require special attention.

An addendum to the Memorandum for Record and Approval of Expenditures is being prepared which will outline in detail the particular investigations that are to be made and the design studies contemplated.

AMERICAN MACHINE AND FOUNDRY COMPANY
CONTRACT DA-069-ORD-1251
(Project TS1-15-C88)

Project Engineer: E R. Thilo

Authorization: By direction of Dr. W. J. Kroeger within the scope of Project TS1-15 and appropriate RADs

OBJECT: Studies of interior ballistics of cartridge actuated devices and preparation of engineering manual of cartridge actuated devices.

STATUS: Contract DA-30-069-ORD-1251 has been placed with the Mechanics Research Department of American Machine and Foundry Company, Chicago. The immediate object of this contract is to prepare a manual of Cartridge Actuated Devices including ballistic performance and engineering data pertinent to catapults, removers, thrusters, and initiators developed by the Ordnance Corps.

The data catalogued will include:

1. Ballistic performance data at several temperatures (velocity, maximum acceleration, maximum rate of change of acceleration, pressure-time curves, velocity-travel, acceleration-travel, etc.)

2. Assembly and sectional photographs of the various devices and cartridges therefor.

3. Assembly, sectional, and installation drawings of the devices and cartridges.

SECTION II

RESEARCH AND DEVELOPMENT

FOR

AIR FORCE SPECIAL WEAPONS COMMAND

DEVELOPMENT OF RELEASE, BOMB, T6
(Project TS1-15-C4)

Project Engineer: J. J. Gricius
Ballistics Phase: J. L. Helfrich

Authorization: OO 121.2/999, FA 452/892, 9 May 1951

OBJECT: To design, develop, and test Release, Bomb, T6.

STATUS: The Office, Chief of Ordnance, advised this arsenal by letter dated 28 May 1953 (OO 113/602; FA 453/1530) that all engineering data and technical responsibility for the subject development were transferred to the Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico. To assist that center in assuming the responsibility, Frankford Arsenal forwarded a program review with related data (letter 26 August 1953, FA 452/1588).

Tentative charges for Cartridge, Bomb Release, T213E1 (normal release), and Cartridge, Initiator, T214, for Initiator, Bomb Release, T10 (emergency release), have been established. Cartridge, T213E1, is loaded with 0.32 gram double base propellant, HES Lot 5140.4B, and an M52A3 electric primer. Cartridge, T214, is loaded with 0.2 gram of propellant, HPC Lot 4258, 0.2 gram A4 black powder igniter, and a caliber .30 No. 26 primer. Charge development was conducted in a simple fixture by measuring the velocity of a propelled mass. Kinetic energy was subsequently obtained from this velocity. The propelled mass for Cartridge, T213E1, was 1.72 pound and for Cartridge, T214, 0.83 pound. These charges were developed to impart a maximum energy of 200 inch pound.

Additional firings are still required to verify the charges. This shall consist of firings over a temperature range of -65° F and 160° F in a fixture which shall simulate the kinetics and friction of the actual bomb rack to be followed by final firings of the prototype bomb rack with no load and 12,000 pound load.

To expedite development, Frankford Arsenal supplemented the contract with the Aircraft Armaments, Inc. to include charge verification. In addition, the contractor is required to manufacture 3500 Cartridge, T213E1, cases of the final design for Air Force environmental tests. Completion of this phase is expected by 9 October 1953.

To date, the contractor has fired approximately 70 rounds in the text fixture. Energy was determined by measurement of copper pressure cylinders. Firings with tentative Cartridge, T213E1, charge imparted an energy of 50 inch pounds. It was concluded that peak pressure was obtained from Electric Primer, M52A3, and not the propellant.

Firings have been conducted with the Cartridge, T213E1, by varying the propellant between 2 grains and 3.5 grains of ballistite composition propellant (Remington express load). Measured energy of the 2-grain charge was 100 inch pound, of the 3.5-grain charge, 200 inch pound. Three firings with the 2-grain charge in the prototype bomb rack at 70° F with 12,000 pound load have been conducted. Hook actuation was successful; however, failure of the roll pin due to plunger impact in the hook retaining group occurred. Modification to the rack is being made to correct this.

The contractor is not required to test the rack by firing with a 56,000 pound load although he is required to assure satisfactory operation at the completion of the development. It is the opinion of this arsenal that a final charge cannot be verified without firings with this maximum load. However, these tests cannot be conducted in view of agreements between the Air Force and Frankford Arsenal that: (1) all tests, other than static, shall be conducted by the Air Force, and (2) damage to the rack may be expected when releasing a 56,000 pound load. To conduct this test as a part of the final charge development, Frankford Arsenal requested concurrence and funds to cover any damage which might occur to the rack.

Frankford Arsenal has also forwarded an estimate of funds required to complete the development as outlined in a Memorandum for Record and Approval of Expenditures.

Figures 44 and 45 are schematic diagrams of the tentative Frankford Arsenal design which is the basis for detailing and development by the contractor. Figures 46 through 49 are photographs of the completed prototype bomb rack. It is to be noted that irrespective of minor changes, the finished bomb rack basically resembles the tentative layout.

DEVELOPMENT OF A BOMB AND STORES EJECTOR SYSTEM
(Project TS1-15-C19)

Project Engineer: J. L. Helfrich
Mechanical Phase: R. W. Markgraf

Authorization: FA 452/1484, 21 Aug 1953
Acceptance Order R-52-889

OBJECT: To develop bomb and stores ejector system.

STATUS: Requirements for a Bomb and Stores Ejector System have been established by The Development Directorate, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico. The requirements were submitted to Pitman-Dunn Laboratories and the Office, Chief of Ordnance, authorized initiation of a project to carry out the necessary work.

General requirements are:

1. The ejection system will consist of two ejectors operated from a single central gas producing chamber.

2. The gas chamber will contain an electrically initiated cartridge which will be connected to the ejectors by hose.

3. Simplicity of design and ease of maintenance shall be emphasized.

4. Operation shall be satisfactory at all temperatures between 160 and -65° F even after exposure for several hours.

5. The system shall be usable for 100 ejections or more, intermittently, over a period of several years with a minimum of maintenance required.

The operation sequence follows:

1. Movement of the bomb rack mechanism shall close the firing circuit to initiate the cartridge. The cartridge will be designed to initiate from a 12 volt source since the aircraft power supply may drop below the normal 28 volts under emergency conditions. The program outlined below does not include development of special primers for this purpose; it assumes the use of standard primer assemblies.

2. Requirements for over-all operating time and synchronization of the two ejectors require further study and clarification. In this regard, it has only been specified that the strokes of the two ejectors in a given system may not differ by more than 1/64 inch.

Thrust and stroke requirements are:

1. Each ejector must be capable of exerting a force of not less than 4000 lb nor more than 5000 lb with two ejectors operating against a single 1800 lb store. The force shall be attained as rapidly as practicable and maintained throughout as much of the ejection stroke as possible.

2. The stroke shall be not less than 5½ inches nor more than 6½ inches with no more than 1/64 inch difference between the two ejectors in a given system.

Installation requirements are:

1. The size of the ejector must not exceed the space envelope 8 in. x 3½ in. x 2½ in.

2. The two ejectors shall be separated by 36 inches.

3. The location and size of the central gas chamber are not specified; these will be studied in view of installation and performance requirements. The size and weight of the chamber will be held to a minimum consistent with these requirements.

4. The ejector will have lug type mounting and the piston will be provided with means for attaching an ejector foot.

5. The cartridge shall be easily installed in and removed from the central chamber.

6. Each ejector must be retractable, preferably by means of a steel spring located within the ejector. The time of retraction is not critical if within a few seconds.

The proposed program is outlined as follows:

1. Administration:

The Air Force Special Weapons Center is sponsoring this project and will be the approving authority for all final designs and performance criteria.

It is proposed that the complete development be performed by a nonmilitary research and development agency under contract to this arsenal.

The Propellant Physics Section will provide technical direction and assistance. including preparation of contract scope and selection, and technical supervision of contractor.

2. Program Plan:

The first phase of the program will consist of the basic interior ballistics studies and preliminary mechanical design of the system. Models will be prepared and evaluated experimentally. This will be followed by detailed design, manufacture, and evaluation of prototypes. When a satisfactory design has been achieved, three complete systems will be prepared, tested, and delivered to the Air Force Special Weapons Center for final evaluation.

Notes on Development Type Materiel, progress reports, and a final report will be furnished.

The contract scope has been prepared and proposals have been solicited and received from nonmilitary research and development agencies. The initial request for bid from the agency selected on the basis of preliminary proposals failed to produce a response from that agency. Requests for bids have been submitted to four additional agencies.

SECTION III

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

PHOTOGRAPHIC AND RECONNAISSANCE LABORATORY

DEVELOPMENT AND MANUFACTURE OF TWO LOW ALTITUDE
PROJECTORS, PHOTOFLASH CARTRIDGE, T12
(Project TS1-15-C12)

Project Engineer: M. H. Long
Ballistics Phase: H. A. Sokolowski

Authorization: Ltr OO 121.2/46C, FA 452/875C, 12 Apr 51

OBJECT: To design, develop, and test Projector, Photoflash Cartridge, T12.

STATUS: At the initiation of this project, Pitman-Dunn Laboratories was assigned the technical supervision of the development and manufacture of two low altitude photoflash projectors for firing Cartridge, Photoflash, T102. In order to accomplish this development within the required time, the technical staff of the Pitman-Dunn Laboratories deemed it necessary to have this project submitted to commercial contractors.

Meetings were held at Frankford Arsenal for the purpose of discussing low altitude photoflash projectors with various commercial facilities and to invite their representatives to submit proposals for the development and manufacture of the projectors. Proposals were submitted and were evaluated following inspection of the commercial establishment and contacts with key personnel of the firms by engineering personnel of Frankford Arsenal.

A contract was then negotiated by the Philadelphia Ordnance District and Contract DA-36-034-ORD-472RD was awarded to Aircraft Armaments, Inc., for the development and manufacture of two low altitude photoflash projectors for firing Cartridge, T102.

The original requirements set forth for low altitude Projector, Photoflash Cartridge, T12 are as follows:

1. Rate of fire - variable between three rounds per second to one round every seven seconds.

2. Operation - automatic, without need for crew attention, except for starting and stopping.

3. Insure projection of at least 400 rounds at maximum rate of fire without breakdown or failure.

4. Temperature - must function from -65° to +160° F.

5. Size and weight - minimum obtainable for a total capacity of 200 charges. Maximum empty weight of 200 pounds desired.

6. Designed to project all rounds from a single exit tube, barrel, port, or carriage.

7. Feed mechanism - suitable device employed.

8. Operate on 24 to 29 volts DC.

9. Power consumption - not to exceed 150 watts at 28 volts DC.

10. Life expectancy - 10,000 rounds fired without major overhaul.

11. Direction of fire -
    Prime position - vertically upward
    Secondary position - horozontally sideward
    Consider any angle between both positions but projector will be fired upon installation.
    Breech end of barrel - two to four feet from skin to ship.

12. Cartridge - aluminum
    Outside diameter, 1.75 - 0.02 in.
    Length, 8.00 - 0.05 in.
    Weight, 1.25 pounds.

At the initiation of this project, personnel from Frankford Arsenal visited Picatinny Arsenal, the agency developing the cartridge, and on this visit the physical size requirements were agreed upon as listed above. However, there was some feeling that due to the length of stroke required by the cycling mechanism of the projector for a cartridge 8 inches long, a cyclic rate of three rounds per second could not be obtained. At this point Wright Air Development Center agreed to reduce the cyclic rate to 2 1/2 rounds per second.

The contractor then submitted to Frankford Arsenal a proposed design for the projector. It was agreed at that time that, in order to obtain the cyclic rate of fire, the best solution would be a projector which would be cycled by expanding propellent gases. Since it is necessary to have certain pressure-time data in order to develop a weapon of this type, it was agreed by the Ordnance Office to transfer the responsibility of the propellant development of the cartridge to Frankford Arsenal so that the propellant development and projector development could proceed concurrently.

In order to complete the necessary engineering involved in this type design, certain values of pressure were agreed upon and it was upon these values that the final projector was manufactured. At the same time, Frankford Arsenal designed a test projector which is comparable to the service projector in caliber, length of travel, cartridge holding mechanism, and initial volume behind the cartridge. Charge development has been conducted with the projector fired in a vertical position similar to the service application. Cartridge recovery was by ground impact.

Velocity for each round was recorded by a chronograph velocity system; pressure within the launcher was measured with a strain gage.

Cartridges, T102, are aluminum, with the exception of the base plate which is steel. Initiation of the cartridge is by percussion firing of the one grain primer. In the test apparatus, however, primer initiation is done electrically to synchronize the recording apparatus with the firing of the weapon. On the functioning of the electric primer, a steel rod is accelerated which strikes the percussion primer of the cartridge.

The percussion primer, in turn, ignites the propellent charge which is contained in a small aluminum cylinder assembled to the steel base cap. On propellant ignition, the unsupported section of the cylinder ruptures, permitting the propellent gas to flow through the vent provided in the steel base cap.

Preliminary charge development has been completed in the test projector and a charge of 1.83 grams of seven perforated M2 propellant, Lot RAD 3002, and 0.25 gram A4 black powder booster has been selected to produce the estimated pressure required for the T12 projector. Chamber pressures and muzzle velocities were measured for Cartridge, T102 (1.47) pounds) conditioned at several temperatures.

Two projectors (Figures 50 and 51) were manufactured and completely assembled. However, certain deficiencies existed in both the projectors and the feed mechanism. Since the requirements of the original contract were terminated, a new contract, No. DA-36-034-ORD-1123 (RD), was negotiated in which the contractor was to correct the deficiencies of the items and make the projector, ammunition box, and feed mechanism operate satisfactorily as a complete unit.

To expedite delivery date of the projectors, it was deemed advisable by both Aircraft Armaments, Inc., and this arsenal, that Aircraft Armaments, Inc. be supplied with a sufficient number of Cartridges, T102, to conduct their own mechanical functioning tests.

Aircraft Armaments, Inc. has requested pressure-time data for the present Cartridge, T102. These charts are being prepared by the Ballistics Section. The contractor will inform the laboratory when recycling tests are completed.

A brief description of the projector follows. The ammunition box was designed to contain 200 cartridges. However, since a rectangular box has to be a very large size for this number of cartridges, only one box is being manufactured. It is felt that the ammunition box would serve a better purpose if it were designed to fit the aircraft into which these projectors are to be installed.

The cartridges will be fed into the projector by a canvas belt containing clips. A booster will be fastened to the ammunition box to help pull the canvas belt containing the cartridges. This will take some of the load off the star wheel which feeds the cartridges into the projector chamber.

When the projector is armed and a cartridge is fed into the chamber, the rear sear which releases the bolt is actuated by a solenoid which receives its pulse from the camera. The bolt carries the cartridge forward until it is stopped by the front sear. The firing pin due to inertia carries forward and fires the primer in the cartridge. As the propellant is set off, the expanding gases actuate a piston which raises the front sear allowing the gases to push the cartridge out of the barrel.

Some of the expanding gases are bled off to operate the bolt return mechanism. As the bolt is being returned a tube with a cam slot is operating a lever mechanism which rotates the star wheel to feed in the next cartridge, and the projector is ready for the next cycle.

The physical characteristics of the projector are as follows:

<u>Size</u>

Projector bare - 8 x 9 x 48 inches long
Ammunition box - 38 x 41 x 11 inches
Booster - 16 x 14 x 9 inches

<u>Weight</u>

Projector bare - 53 pounds
Ammunition box and booster and link belt - 111 pounds
Total weight of projector less ammunition - 164 pounds

The weight of the ammunition box components can be reduced a great deal since the ammunition box was not designed for installation in aircraft.

Bore diameter 1.755 + 0.002

Since this report must cover nineteen months of development of the ballistics phase, the description of the data obtained is broken up into nine phases as outlined below. These follow a rough chronological order, though inspection of the round numbers shows that there was considerable overlapping of the actual firing times.

<u>Phase I.</u> Preliminary development of cartridge test gun mechanism, and vertical velocity measuring system — Rounds 1 through 50

Phase II.	Static tests of various propellants; pressure in rocket chamber measured	Rounds 1S through 42S*
Phase III.	Charge development firings of Army Lot 5280 propellant	Rounds 51 through 108
Phase IV.	Charge development firings of RAD 3002 propellant; tests of horizontal "Lumiline" velocity measurement	Rounds 109 through 137 153 through 172
Phase V.	Tests of Aircraft Armament Prototype Ejector	Rounds 138, 139, 173, 174, 192
Phase VI.	RAD 3002 Static Tests; powder container base thickness studies	Rounds 46S through 66S*
Phase VII.	Firings in test gun modified to simulate initial volume of Aircraft Armaments Prototype Ejector	Rounds 175 through 191 193, 194
Phase VIII.	Static tests; estimate of rocket thrust contribution to velocity	Rounds 67S through 74S*
Phase IX.	Increased charge of RAD 3002 propellant	Rounds 196 through 200

Phase I. Preliminary Development (Rounds 1 through 50)

A test gun, simulating the service ejector in caliber, length of travel, cartridge holding mechanism, and initial volume behind the cartridge holding mechanism, and initial volume behind the cartridge, was designed by LX Branch and manufactured by LR Branch; electrical firing was used for synchronization purposes.

Rounds 1 through 34 were devoted to familiarization with the gun and cartridge, preliminary charge investigation and instrumentation development. Data on these rounds are given in Appendix D; no discussion is given here.

Rounds 34 through 48 constituted a test of the usefulness of a powder container, within the rocket chamber, in promoting uniform ignition and regular burning of the propellant. The attached sketch shows the powder container in place, threaded into the base of the projectile. On propellant ignition, the unsupported section of the aluminum powder container ruptures and the propellent gases break the sealing disk and blow out through the nozzle. Following is a comparison of results obtained from firings with and without the powder container.

*Letter "S" following a round number indicates a static round; i e, a firing of the projectile outside the barrel.

Charge	4 pieces (1.43 grams) Lot HES 4831.8
Igniter	0.12 grams A4 granulation black powder
Projectile weight	1.25 lb
Nozzle area	0.00318 in.^{2}

	Temp	*Max Pressure (psi)*	*Velocity (f/s)*
Without cap	-65	360	154
	70	190	144
	160	95	126
With cap	-65	45	81
	70	125	131
	160	140	138

Inspection of the pressure-time curves confirmed the improved regularity of burning of the rounds in which powder containers were used; on all subsequent firings powder containers were used.

Phase II. Static Tests of Various Propellants (Rounds 1S through 42S)

Except for very short periods at the beginning and end of burning, the pressure inside the projectile propellant chamber is much more than 1.8 times the pressure outside the nozzle; thus flow at the nozzle throat is sonic and does not depend on the outside pressure. This fact makes it possible to experiment with charges by firing the projectile statically outside the gun, since burning is not affected by the gun barrel pressure. This technique was used to investigate the behavior in the projectile with the following propellants and charges: 2.2 and 1.75 grains RAD 3009, 1.38 and 1.73 grams Army Lot 5280, 1.83 and 2.1 grams RAD 3002. For each of these propellants the maximum charge weight shown above is the maximum charge which can be contained in the powder container.

Since the propellant burns as in a rocket, temperature dependence of pressure is extreme. However, inspection of the data in Appendix D shows that even for the larger charges used, the projectile internal pressure does not exceed 11,000 psi; the design maximum is 12,000 psi.

On account of variation in the rocket parameters, only the significant data are presented below in summary form. The other data, and more detailed data on the summarized rounds, will be found in Appendix D.

Propellant and Weight (gm)	*Rocket Parameters (K)*	*Temp (°F)*	*No. of Rounds*	*Pressure, (psi)* *Max*	*Pressure, (psi)* *Powder Container Rupture*
1.75 Army Lot 5280 0.12 A4 igniter	$K_i = 322$, $K_m = 400$, $K_f = 463$	-65	2	3780	650
		70	2	4800	790
		160	2	7340	730
Rad 3002					
2.12 0.1 A4 igniter	$K_i = 326$, $K_m = 400$, $K_f = 463$	-65	1	5770	1440
		70	2	8190	1000
		160	2	9920	1080
1.83 0.25 A4 igniter	$K_i = 285$, $K_m = 350$, $K_f = 405$	-65	2	3850	1720
		70	2	6840	1160
		160	2	7630	2140

Phase III. Charge Development with Army Lot 5280 Propellant (Rounds 51 through 108)

On the basis of the static test data and preliminary firings in the test gun, a charge of 5 pieces (1.73 grams) of Army Lot 5280 propellant, and 0.12 gram A4 granulation black powder igniter, were selected for further investigation. Firing was done vertically. Velocity was measured by mounting a magnet in the projectile and firing through two coils. Pressure was measured by a strain gage mounted normal to the gun tube just ahead of the bolt face.

The following parameters apply for all firings in this phase:

Charge	1.73 grams Army Lot 5280, 0.432 in. long, 0.203 in. OD, 0.04 in. web, 0.12 gram A4 BP igniter

Rocket primers, propellant surface	S_i = 2.37 in.^{2}
	S_m = 2.94 in.^{2}
	S_f = 3.39 in.^{2}
Ratio, propellant surface/ nozzle area	K_i = 322
	K_m = 400
	K_f = 462
Nozzle	A = 0.00734 in.^{2}
Barrel	1.75 in. dia., 24 in. length
Projectile travel to muzzle exit	22.5 in.

To check the pressure measurement system, the pressure-time curves obtained for six rounds were integrated twice to give velocity and travel data. The travel and velocity at muzzle exit obtained in this manner are shown below for comparison with the measured velocity and known travel (22.5 in.).

	Temp (°F)	*Maximum Pressure (psi)*	*Burning Time (sec)*	*Velocity, (f/s) Measured*	*Velocity, (f/s) Integration*	*Travel (in.) Integration*
1.25 lb proj	-65	125	0.028	135	143	25.5
	70	265	0.020	191	141	16.4
	160	330	0.020	210	192	19.8
1.47 lb proj	-65	150*	0.029	137*	137	24.7
	70	230*	0.023	166*	155	21.2
	160	240*	0.022	170*	157	24.8

*Measured data average of two firings; integrated data from single pressure-time curve.

From the above data, it is evident that while the maximum barrel pressure, except at the elevated temperature, was lower than that required for gas operation, velocities were too large to permit increase of charge. Inspection of pressure-travel and velocity-travel curves obtained by these integrations indicated that maximum pressure occurred at 5 to 10 in. travel and that the velocity at 10 in. travel was only 70 to 80 per cent of the muzzle velocity.

Eight 3/8 in. holes were drilled in the barrel wall at 10 in. travel to vent the pressure at this point. Rounds 65 through 108 were fired with this configuration, and are summarized as follows:

Temp (°F)	*No. of Rounds*	*Maximum Pressure (psi)*	*Velocity (f/s)*	*Burning Time (sec)*
70	10	185	134	0.020
-65	10	110	112	0.0260
160	10	190	138	0.021

Note: In Appendix D, the 70° data are separated by the projectile base diameter and strength of sear spring tests. Only data taken using the 1.746 inch projectile base are shown here; since no significant variation of pressure and velocity with sear spring strength was noted, strong and weak sear spring data are not differentiated.

Drilling holes in the barrel reduced the velocity as expected, but, contrary to expectation, the pressure was also reduced. Since 1.73 grams is the largest charge of Army Lot 5280 propellant the projectile will hold, work with this propellant was terminated.

Phase IV. Charge Development with RAD 3002 propellant (Rounds 109 through 137, 153 through 172)

Since earlier firings had shown that propellant Lot RAD 3002 gave a higher pressure and a more rapid rise than Army Lot 5280 (the latter statement is reasonable in view of the larger initial surface area: 3.75 in.^{2} compared to 2.37 in.^{2}), firings were commenced with this charge.

Average values follow (full data in Appendix D):

Charge — RAD 3002; 0.347 inch length, 0.138 inch OD, 0.0256 inch web, 14 pieces (1.83 grams)

Igniter — 0.25 gram A4 granulation black powder

Rocket parameter —
S_i = 3.78 in.^{2}
S_m = 4.63 in.^{2}
S_f = 5.36 in.^{2}
K_i = 285
K_m = 350
K_f = 405

Nozzle Area, A_t = 0.01324 in.^{2}

Projectile Mass (lb)	Temp (°F)	No. of Rounds	Velocity (f/s)	Max Press (psi)	Pwdr Cont Rpt Press (psi)	Remarks
1.47	-65	5	149	288	150	Vertical firings; Magnetic velocity system
	70	6	173 (4)	367	165 (2)	
	160	5	187	507	212	
1.47	-70	13	172 (5)	406 (8)		Horizontal firing; Development of Lumiline velocity system
1.24	-65	5	177 (4)	352		Horizontal firing; Lumiline velocity system-10 ft baseline
	70	10	188	442		
	160	5	207	522		

Note: Numbers in parentheses indicate number of rounds from which data are taken, if different from entry in third column.

With this charge a large increase in peak pressure was obtained without inordinately raising the muzzle velocity. This charge proved satisfactory in the test gun.

Phase V. Tests with Aircraft Armament Prototype Ejector (Rounds 138, 139, 173, 174, 192)

Two series of tests were made firing the charge developed as described in Phase IV with a prototype ejector supplied by Aircraft Armaments, Inc. Full firing data are given in Appendix D.

The first series, which is described in the Final Technical Report,[1] was of two rounds fired 31 July 1952 and 11 August 1952. In both firings, the gun jammed on bolt rearward travel.

The second series of three rounds was fired 27 February 1953 (Rounds 173, 174) and 13 May 1953 (Round 192-Demonstration firing; no data available). Pressure and velocity data indicate performance very similar to that with the test gun. The prototype gun did not cock for any of the three rounds fired.

Phase VI. Static Tests. Powder Container Base Thickness Studies with Propellant Lot RAD 3002 (Rounds 46S through 66S)

Further static firings with a 1.83 gram charge of RAD 3002 propellant were conducted. The thickness and material of the diaphragm sealing the rocket nozzle and

[1]Aircraft Armaments, Inc. Report ER-160 (Contract DA-36-034-ORD-472RD).

the thickness of the powder container wall and base were varied. No significant effects on performance were observed. Full data will be found in Appendix D.

Phase VII. Firings in Test Gun Modified to Simulate Initial Volume of Modified Prototype Ejector (Rounds 175 through 191, 193, 194)

To simulate a proposed design modification of the prototype ejector the test gun was designed as follows:

An elbow leads from a 1¼ inch port in the side of the barrel with center at 1/2 inch projectile travel, to a 1 inch or 3/4 inch pipe pressure reservoir ("gas cylinder") running parallel to the gun barrel. These configurations add 23 or 29 cubic inches, respectively, to the initial volume behind the projectile. A check valve at the entrance port closes when the barrel and gas cylinder pressures are equal.

Pressures were measured at three stations: in the barrel at the projectile base (as before), at the elbow, and at the end of the gas cylinder. These are tabulated at P_1, P_2, and P_3, respectively. Only two of these three pressures were measured for each round. The 8 3/8 inch holes in the barrel were closed for these firings.

The additional initial volume and the added wall area to which heat is transferred lowered the pressure to extremely low values. Because of the difficulties of measuring such low transient pressures, the data are extremely erratic, and are not summarized.

Phase VIII. Static Tests; Estimate of Rocket Thrust Contribution to Velocity (Rounds 67S through 74S)

To determine the contribution of rocket thrust to the velocity of the projectile, two rounds each of the following charges were fired:

1.65 grams RAD 459, 0.25 gram A4 igniter
1.85 grams RAD 5316, 0.25 gram A4 igniter
1.90 grams RAD 459, no igniter
2.12 grams RAD 3002, 0.25 gram A4 igniter

Assuming a discharge coefficient of 7×10^{-3} lb(mass)/lb(force)/sec, the efflux rate was calculated and integrated to give total mass efflux during burning time. The results are tabulated below.

Propellant	*Mass (gm)*	*Mass (lb)*	*Efflux (Calculated) (gm)*
RAD 459	1.65	3.58×10^{-3}	1.63
	1.90	3.20×10^{-3}	1.45
RAD 3002	2.12	4.90×10^{-3}	2.22
	2.12	5.36×10^{-3}	2.43

The agreement of calculated mass efflux and charge mass shows that solid propellant is not being lost through the nozzle.

Calculations based on these mass efflux rates indicate that rocket thrust alone would give the projectile a velocity of about 15 f/s; this amounts to about 10 per cent of the observed muzzle velocity.

Phase IX. Increased Charge of Propellant, Lot RAD 3002 (Rounds 196 through 200)

In an attempt to increase the pressure in the gun with the large initial volume, the charge of propellant, Lot RAD 3002, was increased to case capacity (16 pieces, 2.1 grams). Inspection of the data (rounds 196 through 199) shows that pressure is still substantially below the required operating pressure.

It is concluded that a case capacity charge of the best propellant investigated (the charge tentatively selected), fired in a test gun simulating the initial volume of the prototype ejector, does not provide adequate pressure for cycling of the prototype ejector. Since no larger charge can be used in the cartridge as presently designed, charge development work by LB Branch has been suspended pending cartridge or ejector redesign.

APPENDIX D

APPENDIX D
(Project TS1-15-C12)

TEST FIRINGS, CARTRIDGE, T102
(Rounds 5 through 18)

Powder Description

Powder type	5280
Powder charge	1 gm (except for round 13)
Web	0.04 inch
No. of perforations	7
Diaphragm	10 mils (nitrocellulose)
Temperature	70° F

Performance Data

Round No.	*Velocity (f/s)*	*Max Pressure (psi)*	*Remarks*
5	128.0	400	Velocity computed from Rg = V^2 (sin 2 Theta)
6	-	-	Firing pin pierced primer - failed to ignite powder
7	-	-	No firing pin - primer not ignited
8	-	-	Firing pin too short - primer not ignited
9	-	-	Primer failed to ignite propellant
10*	-	486	Locking mechanism failed to function
11*	-	384	Locking mechanism failed to function
12*	-	196	Chamfer put on locking groove - failed to function
13*	45.9	28	Powder charge in this round - 0.67 gram. Most of the powder was recovered.
15**	145.4	368	Firing modified so that the electric primer does not move projectile
16**	140.5	217	
17**	154.1	471	
18**	-	-	Propellant failed to ignite

*Trench Mortar Sheet (0.5 in. diameter) added to powder charge.
**No locking mechanism used. Powder charge - 1 gram, pieces.

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 20 through 27)

Powder Description

Powder type	11,000
Powder charge	1 gram
Outer diameter of grain	0.372 inch
Length of pieces	0.5 inch
Web	0.09 inch
No. of perforations	1
Diaphragm	10 mils (nitrocellulose)

Rocket Parameters

Round Numbers	*K*	*S* *(in.^{2})*	A_d *(in.)*
20	114	0.88	0.100
21 - 27	200	0.88	0.075

No locking mechanism used

Performance Data

Round Number	*Velocity (f/s)*	*Max Press (psi)*	*Temp (°F)*	*Remarks*
20	107.05	-	70	Instrument failure 0.043 gm powder recovered
21	149.98	221	70	
22	155.10	410	70	
23	141.40	188	70	
24	114.67	147	-65	
26	-	-	-65	Rocket base sheared threads
27	120.54	-	-65	Rocket base sheared threads

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 28 through 33)

Powder Description

Powder type	4831.9
Powder charge	1 gram
Outer diameter of grain	0.245 inch
Length of pieces	0.478 inch
Web	0.09 inch
No. of pieces	2
No. of perforations	1
Diaphragm	10 mils (nitrocellulose)

Rocket Parameters

Round Numbers	K	K_i	K_f	S ($in.^2$)	A_d (in.)
28	250			1.098	0.0750
29	302			1.098	0.0682
30 - 33		445	300		0.0560

Aluminum nozzle
Projectile weight - 1.25 lb
Temperature - 70° F

Performance Data

Round Number	Velocity (f/s)	Max Press (psi)	Remarks
28	18.51	*	
29	-	-	Projectile did not move. 0.34 gram of powder was recovered. The value of K was too low
30	-	-	Powder failed to ignite. Method of crimping unsatisfactory since primer firing breaks crimp. (A new method of crimping is being devised.)
31**	-	*	Projectile loose in gun, rose 20 ft
32**	-	*	Projectile rose 60 ft
33**	60 (approx)	*	Projectile rose 60 ft. No sear used.

*Pressure too low to be measured
**Igniter - 0.12 gram, A4 granulation

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 34 through 48)
Test to Ascertain Usefulness of Cap (Powder Container)

Powder Description

Powder type	4831.8
Outer diameter of grain	0.202 inch
Powder charge	see performance data
Length of pieces	0.486 inch
Web	0.072 inch
No. of pieces	see performance data
No. of perforations	1
Igniter	0.12A4, except Rounds 37 and 39, which had no igniter

Rocket Parameters

Round Numbers	K_f	K_j	K_n	*A (in.^{2})*	A_d *(in.)*
34	350	468	408	0.00293	0.061
35	384	525	458	0.00261	0.058
36, 37	430	575	500	0.00293	0.055
38 - 40	430	575	500	0.00318	0.0636

Aluminum nozzle, except where noted otherwise in the performance data
Projectile weight - 1.25 lb, except where noted otherwise in the performance data

Performance Data

Round Number	*Powder Charge (gm-pieces)*	*Velocity (f/s)*	*Max Press (psi)*	*Temp (°F)*	*Remarks*
34	1.07; 3	76.37	-	70	Pressure too low to measure
35	"	-	-	70	Pressure too low to measure
36	"	96.37	-	70	Pressure too low to measure
38	1.43; 4	143.52	190	70	Oil with grease plug at the end was used in strain gage
41	"	-	160	160	"O" ring in nozzle blown apart
43	"	126.47	95	160	
45	"	154.05	360	-65	Base anodized. Some powder was recovered. No lead seal was used, but no leak occurred.

TEST FIRINGS, CARTRIDGE, T102
(Rounds 34 through 48)
Test to Ascertain Usefulness of Cap (Powder Container)

Performance Data (Cont'd)

Round Number	*Powder Charge gm Pieces*	*Velocity (f/s)*	*Max Press (psi)*	*Temp (°F)*	*Remarks*
- Rounds with cap -					
37	1.07; 3	75.57	-	70	Pressure too low to measure
39	1.43; 4	116.49	90	70	Oil with grease plug at the end was used in strain gage
40	"	131.40	125	70	
42	"	81.12	45	-65	
44	"	138.20	140	160	
46	"	-	80	70	Steel nozzle. Projectile wt 1.47 lb
47	"	81.47	40	-65	Steel nozzle. Projectile wt 1.47 lb
48	"	104.64	100	160	Steel nozzle. Projectile wt 1.47 lb

Note: A cap was used in all rounds hereafter

TEST FIRINGS CARTRIDGE, T102 (Cont'd)
(Rounds 49 and 50)
Experimentation with RAD 3009 Powder

Powder Description

Powder type	RAD 3009
Powder charge	see performance data
Outer diameter of grain	0.432 inch
Length of pieces	see performance data
Web	0.07 inch
No. of pieces	1
No. of perforations	7

Rocket Parameters

Round Number	S_f (in.^{2})	S_i (in.^{2})	S_m (in.^{2})	K_i	K_m	K_f
49	1.67	1.495	1.62	470	509	525
50	2.05	1.740	1.93	547	607	645

Steel nozzle
Projectile weight - 1.47 lb
Temperature - 70° F

Performance Data

(Rounds with Cap)

Round Number	Length of Pcs (in.)	Powder Charge (gm)	Velocity (f/s)	Max Press (psi)	Remarks
49	0.5	1.8	116.88	100	
50	0.6	2.2	208.40	480	Base blew off

STATIC FIRINGS, CARTRIDGE, T102
(Rounds 1S through 7S)

Powder Description

Powder type	RAD 3009
Powder charge	see performance data
Outer diameter of grain	0.432 inch
Length of pieces	see performance data
Web	0.07 inch
No. of pieces	1
No. of perforations	7
Igniter	0.12 gram, A4 granulation

Performance Data
(Rounds with Cap)

Round Number	Powder Charge (gm)	Temp (°F)	Max Press (psi)	Cap Rupture Press	Rocket Parameters
Length of pieces: 0.6 in.					
1S	2.2	70	Al. nozzle - Hole enlarged. 50% of powder recovered		S_i - 1.74 in.^{2}; S_m - 1.93 in.^{2}; S_f - 2.05 in.^{2}; K_i - 547; K_m - 607; K_f - 645; A_d - 0.0636 in.
2S	2.2	70	Steel nozzle		S - 1.74, 1.93, 2.05 in.^{2} K - 451, 500, 531 A_d - 0.0701 inch
3S	2.2	70	Steel nozzle Head threads sheared, base blew out		S - 1.74, 1.93, 2.05 in.^{2} K - 547, 607, 645 A_d - 0.0636 in.
Length of pieces: 0.5 in.					
4S	1.75	70	2180	1980	S - 1.495, 1.62, 1.67 in.^{2} K - 388, 421, 434 A_d - 0.00385 in. (For Rd 4S through 7S)
5S	1.73	70	3210	2230	
6S	1.79	-65	1760	1430	
7S	1.75	160	5020	5020	

STATIC FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 8S through 17S)

Powder Description

Powder type	5280
Powder charge	see performance data
Outer diameter of grain	0.203 inch
Length of pieces	0.432 inch
Web	0.04 inch
No. of pieces	see performance data
No. of perforations	7
Igniter	0.12 gram, A4 granulation

Performance Data
(Rounds with Cap)

Round Number	*Powder Charge (gm)*	*Temp (°F)*	*Max Press (psi)*	*Cap Rupture Press*	*Rocket Parameters*
No. of pieces: 4					
8S	1.38	70	No data - cap blocked gage hole		S_i - 1.89 in.^{2}; S_m - 2.35 in.^{2}; S_f - 2.70 in.^{2}; K_i - 322; K_m - 400; K_f - 462. A_d - 0.086 in. A - 0.00588 in.^{2} (For Rd 8S through 12S)
9S	1.38	165	4020	2520	
10S	1.38	-65	2640	1800	
11S	1.38	70	No data - cap blocked gage hole		
12S	1.38	70	3660	2160	
13S	1.38	70	5920		S - 1.89, 2.35, 2.70 in.^{2} K - 402, 500, 574 A_d - 0.077 in. A - 0.00470 in.^{2} (For Rd 13S and 14S)
14S	1.38	-65	4090		
No. of pieces: 5					
15S	1.67	-65	3000		S - 2.37, 2.94, 3.39 in.^{2} K - 322, 400, 462 A_d - 0.0963 in. A - 0.00734 in.^{2} (For Rd 15S through 17S)
16S	1.72	70	4060		
17S	1.72	165	5890		

STATIC FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 19S through 25S, 27S through 32S)

Powder Description

Powder type	RAD 3002
Powder charge	see performance data
Outer diameter of grain	0.138 inch
Length of pieces	0.347 inch
Web	0.0256 inch
No. of pieces	see performance data
No. of perforations	7
Igniter	0.1 gram, A4 granulation

Performance Data
(Rounds with Cap)

Round Number	*Powder Charge (gm)*	*Temp (°F)*	*Max Press (psi)*	*Cap Rupture Press*	*Rocket Parameters*
No. of pieces: 16					
19S	2.11	70	7560	620	S_i - 4.32; S_m - 5.296; S_f - 6.128
20S	2.12	70	8810	1370	in.^{2}. K_i - 326; K_m - 400; K_f - 463.
21S	2.13	-65	5770	1440	A - 0.01324 in.^{2}. A_d - 0.1298 in.
22S	2.12	-65	*	480	(For Rd 19S through 25S)
23S	2.11	160	10880	1260	
24S	2.12	160	8960	890	
25S	2.12	-65	*	480	
No. of pieces: 14					
27S	1.83	70	6710	1360	S_i - 3.78; S_m - 4.634; S_f - 5.36
28S	1.83	70	6960	950	K_i - 285; K_m - 350; K_f - 405.
29S	1.83	160	7980	1990	A - 0.01324 in.^{2}. A_d - 0.1298 in.
30S	1.83	160	7280	2290	(For Rd 27S through 32S)
31S	1.83	-65	3550	990	
32S	1.83	-65	4150	2440	

*Propellant failed to ignite

STATIC FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 33S through 42S)

Powder Description

Powder type	5280
Powder charge	see performance data
Outer diameter of grain	0.203 inch
Length of pieces	0.432 inch
Web	0.04 inch
No. of pieces	5
No. of perforations	7
Igniter	0.12 gram, A4 granulation

Performance Data
(Rounds with Cap)

Round Number	*Powder Charge (gm)*	*Temp (°F)*	*Max Press (psi)*	*Cap Rupture Press*	*Rocket Parameters*
33S	1.75	70	*	280	S_i - 2.37; S_m - 2.94; S_f - 3.39 in.^{2} K_i - 322; K_m - 400; K_f - 462.
34S	1.75	70	5620	750	A - 0.00734 in^2. A_d - 0.0963 in. (For Rd 33S through 42S)
35S	1.75	70	4980	830	
36S	1.74	-65	3710	650	
37S	1.74	-65	*	330	
38S	1.74	-65	*	330	
42S	1.75	-65	3840	660	
39S	1.75	160	7360	700	
40S	1.75	160	7320	760	
41S	1.75	160	*	-	

*Propellant failed to ignite

TEST FIRINGS, CARTRIDGE, T102
(Rounds 51 through 108)

Powder Description

Powder type	5280
Powder charge	1.73 gm, except where noted otherwise in performance data
Outer diameter of grain	0.203 inch
Length of pieces	0.432 inch
Web	0.04 inch
No. of pieces	Rd 51 - 52, 4 Rd 53 - 108, 5
No. of perforations	7
Igniter	0.12 gram, A4 granulation

Projectile weight - 1.47 lb, except where noted otherwise in performance data 8 3/8 in. holes at 10 in. travel (Rds 62 through 108)
Steel nozzle

Rocket Parameters

Round Numbers	S_i *(in.²)*	S_m *(in.²)*	S_f *(in.²)*	K_i	K_m	K_f	*A (in.²)*	A_d *(in.)*
51 - 52	1.89	2.35	2.70	322	400	462		0.0860
53 - 108	2.37	2.94	3.39	322	400	462	0.00734	0.0963

Performance Data
(Rounds with Cap)

Round Number	*Velocity (f/s)*	*Max Press (psi)*	*Temp (°F)*	*Remarks*
51	130.43	155	70	Powder charge - 1.38 gm
52	120.09	125	-65	Powder charge - 1.38 gm
53	146.13	135	70	
54	132.21	125	-65	
55	174.20	260	160	
56	184.89	330	70	Grease in gage
58	142.05	170	-65	Oil in gage
61	166.10	220	160	Oil in gage

TEST FIRINGS, CARTRIDGE, T102
(Rounds 51 through 108)

Performance Data (Cont'd)

Round Number	Velocity (f/s)	Max Press (psi)	Temp (°F)	Remarks
57	190.94	265	70	Grease in gage, powder charge 1.72 gm Proj wt - 1.25 lb Al. base, steel insert
59	134.87	125	-65	Oil in gage. Otherwise same as Rd 57
60	210.22	330	160	Oil in gage. Otherwise same as Rd 57
8 3/8 in. holes at 10 in. travel in all rd hereafter				
62	-	310	70	Proj wt - 1.25 lb Al. base, steel insert Proj diameter - 1.7413 in.
63	167.61	285	70	Same as rd 62 (velocity at 10 in. travel - 146 f/s)
64	140.25	235	70	Base dia - 1.7464 in.; Proj dia - 1.7412 in. Weak sear spring
65	93.61	70	70	Base dia - 1.7421 in.; Proj dia - 1.7410 to 1.7413 in. Strong sear spring
66	109.54	95	70	Same as Rd 65
67	142.31	220	70	Same as Rd 64
68	129.20	155	70	Same as Rd 64
69	132.56	165	70	Same as Rd 64
70	131.67	160	70	Same as Rd 64
71	119.32	135	70	Same as Rd 65
72	87.93	65	70	Same as Rd 65
73	102.95	130	70	Same as Rd 65
74	133.85	165	70	Base dia 1.746 in.; Proj dia 1.742 in. Strong sear spring
75	137.36	195	70	Same as Rd 74
76	129.99	165	70	Same as Rd 74

TEST FIRINGS, CARTRIDGE, T102
(Rounds 51 through 108)

Performance Data (Cont'd)

Round Number	Velocity (f/s)	Max Press (psi)	Temp (°F)	Remarks
77	135.82	180	70	Same as Rd 74
78	137.85	195	70	Same as Rd 74
79	134.50	180	70	Same as Rd 64
80	133.53	175	70	Same as Rd 64
81	132.66	170	70	Same as Rd 64
82	132.98	170	70	Same as Rd 64
83	139.34	210	70	Same as Rd 64
84	131.76	180	70	Base dia 1.742 in.; Proj dia - 1.742 in. Weak sear spring
85	127.43	155	70	Same as Rd 84. (High spot on base, 1.7458 in.)
86	127.43	160	70	Same as Rd 84
87	139.74	215	70	Same as Rd 84
88	134.03	185	70	Same as Rd 84
89	101.16	75	-65	Same as Rd 74
90	131.00	135	-65	Same as Rd 74
91	112.71	135	-65	Same as Rd 74
92	83.90	55	-65	Same as Rd 74
93	-	-	-65	Same as Rd 74 Failed to fire. Believe A4 was omitted.
94	100.69	70	-65	Same as Rd 74
95	121.75	140	-65	Same as Rd 74
96	120.09	130	-65	Same as Rd 74
97	111.39	95	-65	Same as Rd 74
98	124.72	140	-65	Same as Rd 74
99	146.02	230	160	Same as Rd 74
100	133.25	-	160	Same as Rd 74 Instrumentation failure
101	134.59	185	160	Same as Rd 74
102	131.53	140	160	Same as Rd 74
103	141.16	200	160	Same as Rd 74
104	143.05	190	160	Same as Rd 74
105	138.54	170	160	Same as Rd 74
106	137.02	175	160	Same as Rd 74
107	142.73	185	160	Same as Rd 74
108	151.51	225	160	Same as Rd 74

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 109 through 137)

Powder Description

Powder type	RAD 3002
Powder charge	1.83 grams
Outer diameter of grain	0.138 inch
Length of pieces	0.347 inch
Web	0.0256 inch
No. of pieces	14
No. of perforations	7
Igniter	0.25 gram, A4 granulation

Rocket Parameters

S_i - 3.78 in.^{2}	K_i - 285	A - 0.01324 in.^{2}
S_m - 4.63 in.^{2}	K_m - 350	A_d - 0.1298 in.
S_f - 5.36 in.^{2}	K_f - 405	

Rounds 109 through 124

Projectile wt - 1.47 lb
Steel nozzle

Performance Data
(Rounds with Cap)

Round Number	Temp (°F)	Velocity (f/s)	Max Press (psi)	Cap Rupture Press	Remarks
109	70	-	350		
110	70	-	370		
111	70	165.25	290		
112	70	170.73	370		Integrated velocity - 169.7 f/s at 19.3 in. travel
118	70	179.30	410	200	
119	70	175.71	410	130	
113	-65	136.68	220	110	
114	-65	143.31	285	170	
115	-65	158.47	285	110	
116	-65	159.12	330	190	
117	-65	147.63	320	170	Integrated velocity - 138.7 f/s at 17.0 in. travel

TEST FIRINGS, CARTRIDGE, T102
(Rounds 109 through 137)

Performance Data (Cont'd)

Round Number	Temp (°F)	Velocity (f/s)	Max Press (psi)	Cap Rupture Press	Remarks
120	160	180.82	445	120	
121	160	184.01	520	270	
122	160	196.09	570	180	
123	160	187.96	500	220	
124	160	188.05	500	270	Integrated velocity - 187.2 f/s at 35.4 inches travel.

Rounds 125 through 137

Fired horizontally in test model gun with 8 3/8 in. diameter holes at 10 in. travel
Steel nozzle; Projectile weight - 1.47 lb
Lumiline velocity measurement system being developed in these rounds

Performance Data
(Rounds with Cap)

Round Number	Temp (°F)	Velocity (f/s)	Max Press (psi)	Cap Rupture Press	Remarks
125	70	-	440	290	Difficulties with lumiline system responsible for missing velocities
126	70	181.8	440	220	
127	70	-	430	20	
128	70	-	360	120	
129	70	-	600	100	
130	70	173.9	400	180	
131	70	173.9	430	150	
132	70	173.9	390	200	
133	70	156.9	360	150	
134	70	-	-	-	
135	70	-	-	-	
136	70	-	-	-	
137	70	-	-	-	

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 153 to 172)

Fired horizontally in test model gun with 8 3/8 in. diameter holes at 10 in. travel. Steel nozzle. Projectile weight - 1.236 lb.

Powder Description

Powder type	RAD 3002
Powder charge	1.83 grams
Outer diameter of grain	0.138 inch
Length of pieces	0.347 inch
Web	0.0256 inch
No. of pieces	14
No. of perforations	7
Diaphragm	3 mils (A1)
Igniter	0.25 gram, A4 granulation

Rocket Parameters

S_i - 3.78 in.^{2}	K_i - 285	A - 0.01324 in.^{2}
S_m - 4.63 in.^{2}	K_m - 350	A_d - 0.130 in.
S_f - 5.36 in.^{2}	K_f - 405	

Performance Data
(Rounds with Cap)

Round Number	Temp (°F)	Velocity (f/s)	Max Press (psi)	Cap Rupture Press	Remarks
154	-65	-	490	120	Velocity measured over a 10 ft. base line with lumiline screens
155	-65	183.89	310	90	
156	-65	166.67	280	90	
157	-65	190.48	410	160	
172	-65	166.67	270	90	
153	70	173.91	400	130	
160	70	200.00	520	140	
161	70	173.91	400	130	
162	70	190.48	420	140	

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 153 to 172)

Performance Data (Cont'd)

Round Number	*Temp (°F)*	*Velocity (f/s)*	*Max Press (psi)*	*Cap Rupture Press*	*Remarks*
163	70	210.53	590	100	
164	70	200.00	440	110	
165	70	190.48	410	110	
166	70	188.22	390	100	
167	70	173.91	440	120	
168	70	173.91	410	120	
158	160	210.53	580	160	
159	160	200.00	540	140	
169	160	200.00	470	150	
170	160	222.22	500	170	
171	160	200.00	520	120	

(Rounds 138, 139)
Automatic Ejector Test

Powder Description

Powder type	RAD 3002
Powder charge	1.83 grams
Outer diameter of grain	0.138 inch
Length of pieces	0.347 inch
Web	0.0256 inch
No. of pieces	14
No. of perforations	7
Igniter	0.25 gram, A4 granulation

Rocket Parameters

S_i - 3.78 in.^{2}	K_i - 285	A - 0.01324 in.^{2}
S_m - 4.63 in.^{2}	K_m - 350	A_d - 0.130 in.
S_f - 5.36 in.^{2}	K_f - 405	

Performance Data

Failed to function

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 173, 174, 192)

Demonstration firings in Aircraft Armament gun
Projectile weight - 1.236 lb.
Velocity measured over 10.052 ft. base line with lumiline screens

Powder Description and Rocket Parameters are the same as for the preceding group of rounds (Rounds 153 to 172)

Performance Data
(Rounds with Cap)

Round Number	*Temp (°F)*	*Velocity (f/s)*	*Max Press (psi)*	*Cap Rupture Press*	*Remarks*
173	70	191.5	520		No end pressure measured Gun did not cock
174	70	187.0	480		Same as Rd 173
192	70	-	-		Demonstration firing

STATIC FIRINGS, CARTRIDGE, T102
(Rounds 42*S through 66S)

Powder Description

Powder type	RAD 3002
Powder charge	1.83 grams
Outer diameter of grain	0.138 inch
Length of pieces	0.347 inch
Web	see performance data
No. of pieces	14
No. of perforations	7
Igniter	0.25 gram, A4 granulation
Diaphragm	See performance data

1.236 lb. projectile

Rocket Parameters

S_i - 3.78 in.^{2}	K_i - 285	A - 0.01324 in.^{2}
S_m - 4.63 in.^{2}	K_m - 350	A_d - 0.130 in. (± 0.001)

STATIC FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 42*S through 66S)

Performance Data
(Rounds with Cap)

Round Number	Temp (°F)	Max Press (psi)	Cap Rupture Press	Powder Container Thickness Base	Powder Container Thickness Wall	Remarks
Web: 0.0256 in.						
42*S	70	7350	490			10 mil diaphragm (nitrocellulose)
43S	70	7130	1120			Ditto
44S	160	10160	440			Ditto
45S	160	7210	790			Ditto
46S	-65	4730	920			Ditto
47S	-65	6240	870			Ditto
48S	70	7980	2750			3 mil diaphragm (aluminum)
49S	70	7930	1510			Ditto
50S	-65	5160	1370			Ditto
51S	-65	3160	690			Ditto
52S	160	9800	1950			Ditto
53S	160	10280	2800			Ditto
Web: 0.024 in.						
54S	70	7950	430			2 mil aluminum diaphragm
55S	70	6450	340			Ditto
56S	-65	4440	660			Ditto
57S	-65	4210	940			Ditto
58S	160	7920	540			Ditto
59S	160	8510	710			Ditto
60S	70	7190	730	0.015	0.029	
61S	70	6880	810	0.019	0.0265	
62S	70	6450	180	0.018	0.024	
63S	70	6730	810	0.025	0.026	
64S	70	6720	480	0.025	0.026	
65S	70	6110	810	0.030	0.026	
66S	70	7240	890	0.030	0.026	

*There are two rounds which were numbered 42S; 42*S signifies the second.

TEST FIRINGS, CARTRIDGE, T102
(Rounds 175 through 191, 193, 194)

Fired horizontally in a test ejector which had been modified by the Aircraft Armament Company to simulate the volume of the final design ejector by adding a by-pass at 2 in. of travel, increasing the volume by 26 cu in.

Projectile weight - 1.236 lb

Powder Description

Powder type	RAD 3002
Powder charge	1.83 grams
Outer diameter of grain	0.138 inch
Length of pieces	0.347 inch
Web	0.024 inch
No. of pieces	14
No. of perforations	7
Igniter	0.25 gram, A4 granulation
Diaphragm	3 mils (aluminum)

Rocket Parameters

S_i - 3.78 in.^{2}	K_i - 285	A - 0.01324 in.^{2}
S_m - 4.63 in.^{2}	K_m - 350	A_d - 0.130 in.
S_f - 5.36 in.^{2}	K_f - 405	

Velocity measured over a 5 ft base line with lumiline screens

TEST FIRINGS, CARTRIDGE, T102 (Cont'd)
(Rounds 175 through 191, 193, 194)

Performance Data
(Rounds with Cap)

Round Number	Temp (°F)	Velocity (f/s)	Max Pressure (psi) P_1	P_2	P_3	Remarks
No check valve below P_2						
175	70	150.4	183	-	194	Evidence of gas leak around band covering holes in barrel and at both ends of pipe (mostly around band), in Rd 175 through 177
176	70	170.9	216	-	232	
177	70	150.4	172	-	195	
Check valve in position below P_2						
178	70	155.0	154	-	138	
179	70	146.0	181	-	172	
180	70	141.8	-	171	165	
181	70	148.0	-	196	172	
182	70	140.8	200	183	-	
183	70	143.0	179	168	-	
184	-65	95.2	-	-	-	Pressure too low to measure
185	-65	105.3	-	-	-	Pressure too low to measure
186	-65	114.3	-	-	-	Pressure too low to measure
187	70	133.3	151	-	195	
188	70	130.7	202	-	147	
189	70	136.1	162	107	-	Base of projectile blew off
190	-65	-	-	-	-	Pressure too low to measure
191	-65	-	-	-	-	Pressure too low to measure
192	(Demonstration firing; see preceding group of rounds)					
193	0	133.0	56	-	151	Bourdon gage used with Rds 193 and 194. Unsatisfactory
194	0	138.0	147	-	138	

STATIC FIRINGS, CARTRIDGE, T102
(Rounds 67S through 74S)

Powder Description

Rounds	67S, 68S	69S, 70S	71S, 72S	73S, 74S
Powder type	RAD 459	RAD 5316	RAD 459	RAD 3002
Powder charge	1.65 grams	1.85 grams	1.90 grams	2.12 grams
Outer dia of grain	0.0681 inch	0.0691 inch	0.0681 inch	0.138 inch
Length of pieces	0.321 inch	0.250 inch	0.321 inch	0.347 inch
Web		0.030 inch	0.027 inch	0.024 inch
No. of pieces	60	75	69	16
No. of perforations	1	1	1	7
Igniter (A4 granulation)	0.25 gram	0.25 gram	none	0.25 gram
Diaphragm (aluminum)	3 mils	3 mils	3 mils	3 mils
Temperature	70° F	70° F	70° F	70° F

Performance Data
(Rounds with Cap)

Round Number	*Init Press (psi)*	*Time to Peak (sec)*	*Max Press (psi)*	*Burn Time (sec)*	*Rocket Parameters*
67S	1210	0.0035	6220	0.010	A_d - 0.136 in. A - 0.0145 in.^{2} K_m - 350. S_m - 4.93; S_i - 5.35
68S	1210	0.0035	5820	0.011	S_f - 4.52 in.^{2} (For Rd 67S, 68S)
69S	810	0.007	3160	0.014	A_d - 0.0140 in. A - 0.0152 in.^{2} K_m - 350. S_m - 5.33; S_i - 5.97;
70S	690	0.007	2610	0.014	S_f - 4.69 in.^{2} (For Rd 69S, 70S)
71S	980	0.005	3880	0.011	A_d - 0.144 in. A - 0.0162 in.^{2} K_m - 350. S_m - 5.67; S_i - 6.15;
72S	980	0.0055	3980	0.012	S_f - 5.19 in.^{2} (For Rd 71S, 72S)
73S	1410	0.007	7010	0.009	A_d - 0.142 in. A - 0.0159 in.^{2} K_m - 334. S_m - 5.296; S_i - 4.317;
74S	1720	0.008	7260	0.010	S_f - 6.128 in.^{2} (For Rd 73S, 74S)

TEST FIRINGS, CARTRIDGE, T102
(Rounds 196 through 200)

Fired horizontally in a test ejector which had been modified by the Aircraft Armament Company to simulate the volume of the final design ejector by adding a by-pass at 2 in. of travel, increasing the volume by 26 cu in.

Projectile weight - 1.24 lb

Powder Description

Powder type	RAD 3002
Powder charge	2.1 grams
Outer diameter of grain	0.138 inch
Length of pieces	0.347 inch
Web	0.024 inch
No. of pieces	16
No. of perforations	7
Igniter	0.25 gram, A4 granulation
Diaphragm	3 mils (aluminum)

Rocket Parameters

S_i - 4.317 in.^{2}	K_i - 272	A - 0.01588 in.^{2}
S_m - 5.296 in.^{2}	K_m - 334	A_d - 0.142 in.
S_f - 6.128 in.^{2}	K_f - 386	

Velocity measured over a 5 ft base line with lumiline screens

Temperature - 70° F

Performance Data
(Rounds with Cap)

Round Number	Velocity (f/s)	Time to Peak Press (sec) P_1	Time to Peak Press (sec) P_3	Max Press (psi) P_1	Max Press (psi) P_3	Remarks
196*	154	0.009	0.011	200	151	
197*	172	0.008	0.010	275	173	
198*	157	0.010	0.013	196	188	Time press. exceeded 150 psi
199	163	0.008	0.010	195	206	P_1: 0.006 sec; P_3: 0.005 sec
200	167	0.008	0.009	203	197	P_1: 0.005 sec; P_3: 0.004 sec

*Sear which holds cartridge not used.

DEVELOPMENT AND MANUFACTURE OF TWO MEDIUM ALTITUDE PROJECTORS, PHOTOFLASH CARTRIDGE, T13 (Project TS1-15-C13)

Project Engineer: M. H. Long
Ballistics Phase: H. A. Sokolowski

Authorization: Ltr 00 121.2/46C, FA 452/875C, 12 Apr 51

OBJECT: To develop and manufacture two medium altitude photoflash cartridge projectors.

STATUS: At the initiation of this project, Pitman-Dunn Laboratories was assigned the technical supervision of the development and manufacture of two medium altitude photoflash projectors for firing Cartridge, Photoflash, T103. In order to accomplish this development within the required time, the technical staff of the Pitman-Dunn Laboratories deemed it necessary to have this project submitted to commercial contractors.

Meetings were held at Frankford Arsenal for the purpose of discussing medium altitude photoflash projectors with various commercial facilities and to invite their representatives to submit proposals for the development and manufacture of these projectors. Proposals were submitted and were evaluated following inspection of the commercial establishment and contacts with key personnel of the firms by engineering personnel of Frankford Arsenal.

A contract was then negotiated by the Philadelphia Ordnance District and Contract DA-36-034-ORD-473RD was awarded to Worthington Mower Company for the development and manufacture of two medium altitude photoflash projectors for firing Cartridge, T103.

The original requirements for medium altitude Projector, Photoflash Cartridge, T13 (Figures 52 and 53), as set forth in the contract were as follows:

1. Rate of fire - variable between one round every three seconds to one round every fifteen seconds.

2. Operation - automatic without need for crew attention, except for starting and stopping.

3. Insure projection of at least 100 rounds at maximum rate of fire without breakdown or failure.

4. Temperature - must function from -65° to +160° F.

5. Size and weight - minimum obtainable for a total capacity of 40 charges. Maximum empty weight of 100 pounds desired.

6. Designed to project all rounds from a single exit tube, barrel, port, or carriage.

7. Feed mechanism - suitable device employed. Use of rotating drum, fixed magazine, and various link and belt conveyors should be considered.

8. Operate on 24 to 29 volt DC.

9. Power consumption - not to exceed 150 watts at 28 volts DC.

11. Direction of fire
    Prime position - vertically downward
    Secondary - horizontally sideward
    Breech end of barrel - two to four feet from skin to ship.

12. Cartridge - aluminum
    OD, 3.00 - 0.02 inches
    Length, 10.5 inches
    Weight, 5.5 pounds

At the initiation of this contract it was agreed by both Frankford Arsenal and the contractor that this projector, having a slower cyclic rate than the low altitude projector, could be easily cycled by an electric motor. The contractor proceeded with the development and submitted a proposed design to Frankford Arsenal.

However, at this time, results from illumination studies at Picatinny Arsenal indicated that better illumination characteristics were obtained with a smaller diameter cartridge of a longer length. It was then agreed by all parties concerned that the cartridge would be changed to 2.375 inches diameter by 11 inches long.

The contractor then reworked his proposed design to conform to the new cartridge size. After consulting with Frankford Arsenal, the contractor made test parts to perform functional tests to prove design principles. When the tests were completed, the entire projector design was engineered and manufacture of parts was started. The manufacture of parts was completed and the units were completely assembled and shipped to Frankford Arsenal. All specifications and terms of the original contract were met by the contractor. The two completed projectors were accepted and the contract terminated.

Frankford Arsenal did not immediately test the projectors because cartridges were not available. Before a test program could be set up, Wright Field requested by teletype that the two completed projectors be shipped to their installation where final acceptance tests would be conducted.

A brief description of the projector follows. A spiral feed is utilized in this projector and is operated by spring force. The cartridges are fed toward the center of the spiral to which the barrel and breech mechanism are fastened. The operating mechanism is actuated by a chain drive operated by a variable speed electric motor.

The round is fed into the breech mechanism and a protrusion on the chain carries the breech mechanism forward along with the cartridge and inserts the cartridge into the barrel. A snap ring acts as a stop and also holds the cartridge in place while the round is being fired. The firing is accomplished by a spring loaded hammer. As the round is fired, the snap ring is expanded, releasing the cartridge and allowing the propellent gases to push the cartridges out of the barrel.

A protrusion on the chain on the opposite side of the breech carries the breech rearward and, when the breech is completely withdrawn, a gate on the feed mechanism opens and another round is fed into the mechanism for the next cycle.

The physical characteristics of the ejector are as follows:

Size, 25 inches diameter x 27 inches long
Weight, less ammunition, approximately 80 pounds.

SECTION IV

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

COMMUNICATIONS AND NAVIGATION LABORATORY
(WCENS-2)

CRASH LOCATOR BEACON
(Project TSI-15-C17)

Project Engineer: J. L. Helfrich
Mechanical Engineering Phase: D. MacDonald

Authorization: MIPR No. MCREXA 50074-OD, 28 Apr 50

OBJECT: To develop a catapult for ejection of the crash locator beacon and to develop a parachute ejector for the beacon.

STATUS: A program for concluding this development has been outlined based on clarification by the sponsoring agency (Communications and Navigation Laboratory, Wright Air Development Center) of the performance requirements, as follows:

Separation velocity	80 f/s minimum
Acceleration	50 g maximum
Max rate of change of acceleration (g/sec)	Not specified
Ejected weight	45 lb
Catapult insertion depth into beacon assembly	7 to 8 inches
Catapult collapsed length	15 inches
Catapult weight	Not specified
Catapult type	Open system acceptable

The program plan, including time and cost estimates of the development work, as well as procurement of test models and prototypes, has been submitted to the Office, Chief of Ordnance, and to the sponsoring agency. Approval has been received and the necessary funds are being forwarded.

A coordinated experimental evaluation program is in progress, including static ground launchings at Frankford Arsenal, high velocity track launchings at Edwards Air Force Base, and actual flight tests at El Centro, California.

Static Line Tests. To study the feasibility of triggering the beacon parachute by means of a static line, tests were conducted by Frankford Arsenal in association with Greer Hydraulics at the Naval Aviation Supply Depot, Philadelphia, Pa.

Each of the following tests was photographed from three angles. These movies have been forwarded to Wright Air Development Center for review.

Test No. 1
2/18/53

Estimated beacon velocity	100 f/s
Parachute diameter	10 ft
Pack cover	Stainless steel
Static line, 750 lb test	40 ft long

The detents attaching the stainless steel pack cover to the beacon failed to uncurl. As a result, the wire cable attaching the static line to the pack cover failed in tension. The pack cover did not pull free from the beacon, hence the parachute did not open.

Test No. 2
2/18/53

The detents were modified to reduce the force required for separating the pack cover from the beacon. In addition, heavier cable was used between the static line and the pack cover.

Estimated beacon velocity	100 f/s
Parachute diameter	10 ft
Pack cover	Stainless steel
Static line 750 lb test	40 ft long

The outer and telescoping tubes passed the beacon during ascent and then, while descending, they hit and bounced off the open chute. The beacon descent was stable.

Test No. 3
2/18/53

Estimated beacon velocity	100 f/s
Parachute diameter	12 ft
Pack cover	Stainless steel
Static line, 750 lb test	30 ft long

The parachute opened during ascent, partially collapsed in turning over due to high wind velocity, and then re-opened fully on descent.

Test No. 4
2/19/53

Estimated beacon velocity	80 f/s
Parachute diameter	12 ft
Pack cover	Stainless steel
Static line, 750 lb test	30 ft long

The apex of the beacon flight was relatively low, which was attributed to the low velocity cartridge and the short static line. Several holes were made in the parachute in passing the pack cover detents on opening.

Test No. 5
2/19/53

Estimated projectile velocity	100 f/s
Parachute diameter	10 ft
Pack cover	Stainless steel
Static line, 750 lb test	60 ft long

These initial conditions produced optimum results utilizing the static line for opening the parachute. The descent velocity of the beacon was greater than that desired. Several holes were burned into the parachute during separation of the catapult tubes.

Ballistic Development. Communications and Navigation Laboratory, Wright Air Development Center requested that this arsenal supply cartridges which will impart a 60 f/s velocity to the beacon for tests to be conducted on the rocket propelled sled at Muroc. In view of the fact that there was a supply of Cartridges, Remover, M29A1 on hand at this arsenal, exploratory firings were conducted using Cartridges, M29A1. These firings yielded an average velocity of 70.2 f/s and 81 g maximum acceleration.

On the basis of these results a reduction of propellant mass was considered. Four cartridges loaded with 13 grams of A1 granulation black powder produced an average of 64.8 f/s velocity and 77 g maximum acceleration.

In view of the urgent need for cartridges, sufficient time did not remain for further development. Cartridges loaded with this latter charge were shipped to Muroc.

A five tube, closed type catapult, designed to give a final velocity of approximately 100 f/s and identified as Catapult, Beacon, T13E2, is being manufactured and is scheduled for delivery in December 1953 and for test firing soon thereafter.

Parachute Release. Frankford Arsenal has been relieved of responsibility for further development on the parachute release.

Initiators and Generators. Initiator, Beacon Catapult, T6E1, a mechanical inertia type generator, and Initiator, Beacon Catapult, T6E2, a spring generator, were tested and found impractical. For this application, the rotary type generator is not practical. A more recent design, Initiator, Beacon Catapult, T6E3 (Figure 54), is intended to function when a force of 3 g is applied to the initiator in a plane normal to its central axis. It is omnidirectional since it will function with the force applied from any direction in this normal plane.

The actual operation of this device requires the application of a force of 3 g or more to the pendulum in order to move it through an arc large enough to free it from the restraint of the cantilever type spring. Conversely, any force less than 3 g will not be sufficient to operate the mechanism.

Since the submitted design is only a test model for checking the basic operating principle, provision would have to be made in a service model for caging the pendulum in a safe position as well as providing for manual operation. However, subsequent to this latest idea, it was agreed that this arsenal will discontinue work on the initiators, since a suitable commercial product has been obtained by the Air Force.

Parachute Ejector. Present design trend has been to operate the ejector without a static line. By virtue of its position with respect to the outside container, a latch-operated ejector has been designed which is completely independent of any lanyard pull. The unit is completely "safetied" and its functioning depends solely on the stroke of the catapult platform in relation to the outside container. This proposal is shelved at present in favor of the following design.

In cooperation with W. L. Maxson Corporation, an electrically fired unit has been developed. The ejector is essentially of the same configuration as in the former design, with the exception that the breech firing mechanism has been completely replaced by an electrically operated firing device. The over-all length of the unit has been foreshortened in compliance with the contractor's request. The unit is thus made lighter and occupies less space with the same performance characteristics. To achieve this performance, however, it was necessary to resort to a denser material for the slug, in the form of Mallory metal, to obtain the previous performance (Figure 55). Another feature of this design has been the incorporation of two primers fired in series. Also, it will be observed that the slug has been redesigned to allow a greater volume of gas expansion without reducing effective stroke and to utilize a nylon cord as the connecting link between the slug and the parachute cover. Several units have been manufactured by W. L. Maxson Corporation and further tests have been scheduled.

SECTION V

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

AERO MEDICAL LABORATORY
(WCRDB)

DESIGN AND DEVELOPMENT OF CATAPULT,
AIRCRAFT PERSONNEL TRAINING, T14
(INDOCTRINATION CATAPULT)
(Project TS1-15-C20)

Project Engineer: H. A. Sokolowski
Mechanical Engineering Phase: R. Markgraf

Authorization: MIPR (33-038) R51-157 ORD

OBJECT: Design and develop a catapult for use with the All American Engineering Company ejection seat trainer.

STATUS: Forty-five lots of Cartridges Catapult, T157 have been loaded at Picatinny Arsenal and shipped to Frankford Arsenal for ballistic test and distribution. The first 36 of these lots have been tested and accepted in accordance with the military requirements (Wright Air Development Center).

To expedite cartridge acceptance, a correlation test was conducted to ascertain the feasibility of using the horizontal tester in addition to the indoctrination tower. A series of five firings done on the horizontal tester is compared with the ballistic acceptance test for that lot (Lot PA-163-4) on the tower in Catapult, Aircraft Personnel Training, T14E1-4.

Firing Position	Height of Travel (ft)	Velocity (f/s)	Maximum Acceleration (g)	Maximum Acceleration Std Dev	Maximum Rate of Change of Acceleration (g/sec)	Maximum Rate of Change of Acceleration Std Dev
Vertical	12.3	28.2	11.0	1.27	158	21
Horizontal	-	30.6	9.7	1.06	144	17

The high acceleration observed in the vertical test firings is attributed to the high frictional forces between the seat and the track. The ambient temperature was 32° F causing sluggish operation of the gear shafts by increasing the viscosity of the lubricating grease.

Subsequently, another test was conducted on the horizontal tester using the same cartridge lot in the test catapult. The average performance for ten firings (8.4 g maximum acceleration, 153 g/sec maximum rate of change of acceleration, and 27.1 f/s velocity) compares favorably with the data previously obtained with this catapult in vertical firings. In view of these results, acceptance tests have been conducted horizontally as well as vertically.

Frankford Arsenal has received the 22 Catapults, Aircraft Personnel Training, T14E1, for which a contract had been placed. Ten of these catapults have been tested in accordance with the military requirements. A summary of results obtained in the acceptance tests of both catapults and cartridges is given in Appendix E.

All ten catapults have been shipped, as were 5000 cartridges (1000 with each two catapults) to Air Force bases as specified in teletype from HQ, OOAMA Hill Air Force Base, Utah, received 6 May 1953.

The plastic (polyethylene) closure disc used in the manufacture of the first 12,000 cartridges is susceptible to cracking under long term storage or conditioning at elevated temperatures. This is attributed to the migration of propellent constituents used in double base smokeless propellants.

Several methods of improving the closure are under consideration:

1. A metal disc utilizing a neoprene "O" ring to provide the required hermetic seal. This disc would be very thin in the center to permit rupture at a low pressure, but heavy on the periphery to support the crimping of the case into the "O" ring. The metal must be compatible with the case material to prevent galvanic action and impede corrosion. The model shop is fabricating closure discs in accordance with drawing LX-18-3-1 (Figure 56). Evaluation of these discs will commence as soon as they are available.

2. A thin metallic cup, sealed to the case by a low temperature solder or some other suitable means. The material requirements for this type closure disc would be the same as those above. Due to the difficulty in sealing, no work has been done with this type disc.

3. A stable coating of the underside of the plastic (polyethylene) closure that will impede or prevent the undesired migration. This coating would be applied in a manner similar to that used in high vacuum metalizing.

4. The use of another plastic that will resist migration, such as Teflon or Kel-F. The methods of fabricating or molding these materials are limited since they are relatively new.

APPENDIX E

APPENDIX E
(Project TSI-15-C20)

Summary of Performance Data on Cartridge Acceptance

Cartridge Lot	Velocity f/s	Velocity Std Dev	Maximum Acceleration g	Maximum Acceleration Std Dev	Maximum Rate of Change of Acceleration g/sec	Maximum Rate of Change of Acceleration Std Dev
PA 163-1	27.3	0.97	10.3	1.04	155	16
PA 163-2	27.4	0.73	10.6	0.76	166	19
PA 163-3	27.4	0.75	10.6	0.76	162	19
PA 163-4	28.2	0.85	11.0	1.27	158	21
PA 163-5	28.3	0.99	8.5	0.50	142	18
PA 163-6	28.4	0.62	8.9	0.39	160	18
PA 163-7	30.4	1.61	10.1	1.41	176	18
PA 163-8	30.1	1.68	9.7	1.16	180	19
PA 163-9	30.7	1.22	10.5	1.03	184	11
PA 163-10	27.0	1.11	7.8	0.61	137	13
PA 163-11	28.1	0.71	8.8	0.61	136	13
PA 163-12	26.9	0.97	8.0	0.81	145	20
PA 163-13	29.0	1.66	9.5	1.34	170	19
PA 163-14	29.2	1.11	9.9	1.39	138	25
PA 163-15	27.7	2.00	8.5	1.46	120	19
PA 163-16	28.8	1.56	8.7	1.30	143	18
PA 163-17	29.2	0.81	9.2	0.76	138	11
PA 163-18	26.9	1.27	7.5	2.32	109	17
PA 163-19	27.5	1.47	8.1	1.24	127	27
PA 163-20	26.7	1.34	7.6	0.84	114	11
PA 163-21	29.0	1.99	9.1	1.56	135	20
PA 163-22	28.6	2.36	9.1	1.68	128	18
PA 163-23	26.8	1.73	7.9	1.56	128	36
PA 163-24	28.1	0.78	8.8	0.77	139	24
PA 163-25	27.9	2.31	8.7	1.54	141	28
PA 163-26	27.2	0.82	8.4	0.58	141	26
PA 163-27	27.6	1.29	8.5	0.79	137	23

Summary of Performance Data on Cartridge Acceptance (Cont'd)

Cartridge Lot	Velocity f/s	Velocity Std Dev	Maximum Acceleration g	Maximum Acceleration Std Dev	Maximum Rate of Change of Acceleration g/sec	Maximum Rate of Change of Acceleration Std Dev
PA 163-28	27.8	1.58	8.5	1.14	149	24
PA 163-29	27.5	1.27	8.4	0.87	160	14
PA 163-30	27.3	2.27	8.4	1.49	165	39
PA 163-31	26.8	1.50	7.9	0.71	147	29
PA 163-32	27.4	0.79	8.2	0.62	158	13
PA 163-33	26.8	2.47	8.2	1.57	168	36
PA 163-34	26.0	1.53	7.3	0.92	165	36
PA 163-35	25.4	0.79	7.2	0.62	147	21
PA 163-36	24.9	1.80	7.0	1.31	143	34

Catapult No.	Velocity f/s	Velocity Std Dev	Maximum Acceleration g	Maximum Acceleration Std Dev	Maximum Rate of Change of Acceleration g/sec	Maximum Rate of Change of Acceleration Std Dev
T14E1-3	27.3	0.97	10.3	1.04	155	16
T14E1-4	28.2	0.85	11.0	1.27	158	21
T14E1-5	26.1	1.91	7.9	1.92	128	18
T14E1-7	26.6	0.63	8.0	1.20	112	17
T14E1-8	26.2	0.50	7.5	0.57	111	7
T14E1-9	27.9	2.79	10.7	1.69	140	38
T14E1-10	24.7	0.87	6.5	1.07	111	27
T14E1-11*	23.4	1.48	4.3	0.98	68	22
T14E1-23	26.7	1.89	9.5	1.47	140	18
T14E1-24	26.7	0.91	9.5	0.70	140	14

Note: All catapults have been tested with cartridge Lot PA 163-4, except Catapult, T14E1-3, which was tested with Cartridge Lot PA 163-1.

*This catapult has been inadvertently shipped; however, it has been recalled prior to being used in the field. It is believed that the results shown are erroneous; defective instrumentation was used. Firing tests are in progress for verification.

STUDY OF CATAPULT WITH CARTRIDGE, AIRCRAFT PERSONNEL, M3
(Project TSI-15-C23)

Project Engineer: H. A. Sokolowski
Mechanical Engineering Phase: R. Markgraf

Authorization: Verbal from WADC and FA,
Minutes, Meeting, 10 June 1953 (LC)

OBJECT: To re-evaluate the performance of Catapult with Cartridge, Aircraft Personnel, M3, and to explore possible avenues for improvement of this device.

STATUS: Radford Ordnance Works has manufactured and forwarded to this Arsenal approximately 800 pounds of H8 propellant (Lot OAC-28-52) for Cartridge, Catapult, M36, for use in Catapult with Cartridge, Aircraft Personnel, M3. The propellant was manufactured in 2.66 inch lengths with a 0.308 inch OD and a 0.115 inch web. Firings were conducted utilizing several propellant masses. The performance data are summarized:

Average Performance Data

	Propellant			*Velocity (f/s)*			*Acceleration (g)*			*Rate of Change of Acceleration (g/sec)*		
No. Rd	*Weight (gm)*	*No. Pc*	*Temp (°F)*	*Max*	*Avg*	*Min*	*Max*	*Avg*	*Min*	*Max*	*Avg*	*Min*
5	190	40	-65	73.3	71.7	70.3	13.8	13.1	12.4	150	121	105
5			70	76.5	76.0	75.1	19.2	16.5	15.4	115	106	96
5			160	84.2	83.4	82.6	20.1	19.6	18.9	200	180	173
3	194	41	70	80.1	76.7	74.9	17.2	16.4	15.8	113	105	96
3			70	78.0	77.6	77.2	17.0	16.4	16.0	118	108	90
3			160	84.7	84.4	84.3	20.8	20.7	20.5	211	203	196
3	200	42	70	80.7	80.1	79.2	17.7	16.8	15.8	135	123	107
3	200	42	160	88.5	87.9	87.6	21.2	20.8	20.4	205	182	163

In view of the results obtained with the 194-gram charge, the second series of firings was conducted using new inner and telescoping tubes to determine whether this charge would deliver the minimum velocity required (78 f/s) at 70° F with a new catapult. Since it did not meet the requirement, an additional piece of propellant was used in subsequent firings. On the basis of results from these firings, a charge of 199 ± 1.5 grams was recommended to Picatinny Arsenal for loading into Cartridge, M36.

Ballistic Development (Cartridge, Catapult, T109E2). In view of the excessive accelerations obtained with the H8 propellants, particularly at 160° F, experimental firings were conducted with propellants developed for rocket use. The temperature dependence of these propellants is considerably lower; the coefficient of burning rate is as low as 0.2 per cent per degree Fahrenheit.[1,2] Following is a summary of two firings at each condition with propellant, Lot HES 5251.3B, in 2.0 in. lengths and 50 grains of A1 granulation black powder igniter.

Propellant			Average Performance Data		
No. Pc	Weight (gm)	Temp (°F)	Terminal Velocity (f/s)	Maximum Acceleration (g)	Maximum Rate of Change of Acceleration (g/sec)
36	180	-65	66.2	11.1	157
		70	69.2	10.8	101
		160	81.1	17.4	141
39	195	-65	69.9	11.9	171
		70	73.6	12.9	113
		160	86.3	20.0	174

Firing with this propellent lot was terminated in view of the low performance level at -65° and 70° F.

Study with this type propellant, similar but not identical in composition, continued. A series of two firings at each condition with 180 grams propellant, Lot 5251.3, in 2.0 in. lengths yielded the following average performances:

	Average Performance Data		
Temp (°F)	Velocity (f/s)	Maximum Acceleration (g)	Maximum Rate of Change of Acceleration (g/sec)
-65	77.3	15.4	218
70	81.7	17.6	175
160	85.1	20.1	177

Since this propellant arrangement appeared to show considerable promise, additional tests were conducted with a reduced mass (173 grams). Five cartridges were fired at each condition; the data obtained are summarized as follows:

[1]OSRD 5824 (Conf) "Effect of Pressure and Temperature on Burning Rate," March 1946.

[2]OSRD 5827 (Conf) "Burning-Rate Studies," January 1946.

Temp (°F)	Velocity (f/s)	Maximum Acceleration (g)	Maximum Rate of Change of Acceleration (g/sec)
	Average Performance Data		
-65	74.4	14.1	181
70	79.8	17.3	184
160	85.2	20.2	253

The acceleration and rate of change of acceleration obtained from several of the firings were excessive at the elevated temperature.

Studies were continued with a view to improving performance by reducing the case volume by inserting five inert plastic rods, thereby increasing the loading density. In addition, the mass of A1 black powder igniter was increased from 50 grains to 65 grains. This arrangement produced the following average performances for two firings at each condition:

Temp (°F)	Velocity (f/s)	Maximum Acceleration (g)	Maximum Rate of Change of Acceleration (g/sec)
	Average Performance Data		
-65	75.0	14.6	155
70	78.6	17.1	187
160	81.3	18.4	186

Since the velocity at 70° F approaches the lower limit, an increased propellent charge was considered. This was accomplished by reducing the number of pieces of plastic to four and including another piece of propellant (total of 36 pieces weighing 180 grams). Six cartridges were loaded with this charge arrangement; the average results from two firings at each of the temperatures follow.

Temp (°F)	Velocity (f/s)	Maximum Acceleration (g)	Maximum Rate of Change of Acceleration (g/sec)
	Average Performance Data		
-65	75.8	16.0	164
70	81.7	19.7	165
160	83.5	19.9	179

~~The maximum acceleration obtained for firings at 70° F was excessive.~~ Although the results from firings with this propellant show considerable promise, work has been terminated pending receipt of additional funds.

Reduced Volume Catapult. Two Catapults, M3, were modified to reduce the initial and final volumes by eliminating the spacer between the telescoping and outer tubes which permitted a diametral reduction of the outer tube. In addition to reducing the volumes, this modification changed the ratio of final to initial volume significantly.

A limited number of experimental firings has been conducted utilizing these catapults. The average data obtained for two firings with each condition are shown below.

Propellant		*Average Performance Data*		
Lot	*Mass (gm)*	*Velocity (f/s)*	*Maximum Acceleration (g)*	*Maximum Rate of Change of Acceleration (g/sec)*
OAC-28-52	133	87.1	20.9	291
"	108	69.6	12.7	162
"	127	79.5	18.9	227
HES 5130.12	128	75.3	12.2	138

All the above firings were done at 70° F and all the cartridges contained 65 grains of A1 granulation black powder igniter. Round-by-round data for these firings, as well as all other firings summarized in this report, are shown in Appendix F. Ballistic development with these catapults was terminated pending receipt of additional funds.

Cartridge, M36, Rupture Tests. An investigation to determine the pressure required to rupture the case of Cartridge, M36, was commenced. Six cartridges, two each with 40, 50, and 65 grains of A1 granulation black powder igniter only, were fired. None of the cartridge cases ruptured; the only visible effect was a bulging of the base which increased with charge.

APPENDIX F

APPENDIX F
(Project TSI-15-C23)

FIRING DATA OF H8 POWDER ACCEPTANCE TESTS
(Using Catapults, M3)

Powder Description

Lot	OAC 28-52
Outer diameter of grain	0.308 inch
Web	0.115 inch
Number of perforations	1
Igniter grains and granulation	65 A1
Diaphragm	5 mils (magnesium)
Length of pieces	2.66 inches
No. of pieces	
Rounds 1693 to 1707	40 pieces
Rounds 1733 to 1735	41 pieces
Rounds 1744 to 1749	42 pieces
Powder charge	See performance data below

Performance Data

Round No.	*Powder Charge (gm)*	*Temp (°F)*	*Velocity (f/s)*	*Accel (g)*	*Rate of Accel (g/sec)*	*Initial Accel (g's)*
1693	189.3	70	75.30	15.4	109	2.2
1694	189.0	70	-	15.5	102	1.3
1695	189.7	70	75.09	19.2	115	2.8
1696	189.9	70	76.38	16.3	110	2.0
1697	190.0	70	76.47	16.2	96	1.9
1698	189.0	-65	70.47	12.9	150	2.6
1699	189.0	-65	70.25	13.2	113	0.6
1700	190.4	-65	72.96	12.4	130	0.
1701	189.3	-65	73.86	13.8	117	0.
1702	189.7	-65	70.80	13.1	105	1.0
1703	189.4	160	83.92	19.9	200	0.
1704	189.0	160	82.61	19.1	173	0.
1705	189.5	160	83.62	20.0	173	2.7
1706	189.6	160	84.24	20.1	177	0.
1707	190.3	160	82.69	18.9	175	0.
1712	193.7	70	74.89	15.8	-	0.
1713	194.0	70	76.94	16.3	96	0.
1714	193.7	70	80.11	17.2	113	0.
1715	194.0	160	84.66	20.8	211	0.
1716	194.0	160	84.43	20.8	204	0.
1717	194.6	160	84.25	20.5	196	0.
1733	194.0	70	77.20	16.0	90	0.6
1734	194.0	70	77.65	16.2	116	0.3
1735	194.0	70	78.02	17.0	118	0.7
1744	200.3	70	79.24	15.8	128	0.7
1745	199.2	70	80.40	16.8	107	1.0
1748	199.9	70	80.76	17.7	135	2.3
1746	199.5	160	88.45	20.9	205	1.9
1747	200.0	160	87.60	20.4	163	1.8
1749	194.8	160	87.83	21.2	178	1.9

FIRING DATA OF M8 POWDER ACCEPTANCE TESTS - (Cont'd)
(Using Catapults, M3)

Powder Description

Lot	HES 5251.3B
Outer diameter of grain	0.369 inch
Web	0.137 inch
Number of perforations	1
Igniter grains and granulation	50 A1
Number of pieces	36
Length of pieces	2.0 inches
Disc	5 mils (magnesium)
Powder charge	See performance data below

Performance Data

Round No.	Powder Charge (gm)	Temp (°F)	Velocity (f/s)	Accel (g)	Rate of Accel (g/s)	Ignition Delay (sec)
1646	180.2	70	72.85	- - - - - - no data - - - - - - - -		
1647	180.0	70	67.39	10.8	101	0.
1648	180.0	160	81.29	17.7	132	0.
1649	179.8	160	80.85	17.1	149	0.
1650	180.0	-65	65.39	10.2	157	0.08
1651	180.0	-65	67.91	11.8	156	0.11
1652	195.0	70	73.60	13.1	116	0.03
1653	195.0	70	73.55	12.6	110	0.025
1656	195.1	160	85.51	18.8	177	0.
1657	195.0	160	87.10	21.1	171	0.
1661	195.2	-65	69.79	11.8	169	0.07
1662	195.0	-65	70.06	11.9	173	0.065

FIRING DATA OF H8 POWDER ACCEPTANCE TESTS - (Cont'd)
(Using Catapults, M3)

Powder Description

Lot	HES 5251.3
Outer diameter of grain	0.37 inch
Web	0.137 inch
Number of perforations	1
Igniter grains and granulation	50 A1
Number of pieces	36
Length of pieces	2.0 inches
Diaphragm	5 mils (magnesium)
Powder charge	See performance data below

Performance Data

Round No.	*Powder Charge (gm)*	*Temp (°F)*	*Velocity (f/s)*	*Accel* (g)*	*Rate of* Accel (g/sec)*	*Ignition* Delay (sec)*
1687	180.0	70	81.81	17.6	173	0.03
1688	180.3	-65	no data	11.1	135	0.07
1689	180.4	160	84.43	13.8	200	0.
1690	180.0	70	81.33	10.8	102	0.
1691	180.0	-65	76.23	8.8	124	0.08
1692	180.0	160	83.38	11.6	124	0.
1708	179.8	70	81.53	17.5	177	0.02
1709	180.0	-65	77.27	15.4	218	0.04
1710	179.8	160	84.31	21.1	204	no data
1711	180.0	160	85.88	19.1	149	no data

***Note: Due to electronic difficulties, all data for these rounds, except the velocities, are questionable and are included for information only.**

FIRING DATA OF H8 POWDER ACCEPTANCE TESTS - (Cont'd)
(Using Catapults, M3)

Powder Description

Lot	HES 5251.3
Outer diameter of grain	0.37 inch
Web	0.137 inch
Number of perforations	1
Igniter grains and granulation	50 A1
Number of pieces	35
Length of pieces	2.0 inches
Diaphragm	5 mils (magnesium)
Powder charge	173 grams

Performance Data

Round No.	*Temp (°F)*	*Velocity (f/s)*	*Accel (g)*	*Rate of Accel (g/sec)*	*Ignition Delay (sec)*
1718	70	80.00	16.7	161	0.016
1719	70	79.85	17.5	180	0.016
1720	70	79.78	17.5	184	0.016
1721	70	80.37	17.8	198	0.016
1722	70	78.87	17.2	197	0.016
1723	-65	73.67	13.7	no data	0.05
1724	-65	72.05	12.9	140	0.025
1725	-65	74.44	16.1	249	0.116
1731	-65	79.60	14.3	174	0.042
1732	-65	-	13.3	161	0.033
1726	160	83.20	20.6	236	0.
1727	160	84.41	19.1	272	0.
1728	160	91.31	22.0	249	0.
1729	160	84.57	20.1	271	0.
1730	160	82.57	19.5	238	0.

BALLISTIC TEST
OF THE
FIRST CARTRIDGES, M36, LOADED BY PICATINNY ARSENAL
(Rounds 1736 to 1743)

Powder Description

PA Lot	168-1
Powder type	5130.14B
Outer diameter of grain	0.3 inch
Web	0.11 inch
Number of perforations	1
Igniter grains and granulation	65 A1
Diaphragm	5 mils (magnesium)
Vertically fired	Propelled mass 350 lb

Performance Data

Round No.	*Temp (°F)*	*Velocity (f/s)*	*Init Accel (g)*	*Max Accel (g)*	*Rate of Accel (g/sec)*	*Max Press (psi)*	*Ignition Delay (sec)*	*Burning Time (sec)*
1736	70	81.03	1.7	18.2	139	2560	0.02	0.223
1737*	70	79.14	2.5	17.2	101	2280	0.02	0.230
1738	-65	73.79	1.8	13.9	114	1860	0.02	0.238
1739	-65	76.54	2.0	13.9	130	1930	0.02	0.228
1742	-65	80.81	1.7	16.1	170	2210	0.03	0.214
1740	160	87.21	3.3	20.8	162	2750	0.01	0.180
1741	160	86.94	2.8	20.2	167	2660	0.01	0.180
1743	160	87.24	2.5	21.6	148	2790	0.01	0.198

*Cartridge damaged before firing

CHARGE DEVELOPMENT

Powder Description

Lot	HES 5251.3
Powder charge	173 grams
Outer diameter of grain	0.37 inch
Web	0.137 inch
Number of perforations	1
Igniter grains	65
Number of pieces	See performance data below
Length of pieces	2.0 inches
Diaphragm	5 mils (magnesium)

Performance Data

Round No.	*Temp (°F)*	*Velocity (f/s)*	*Accel (g)*	*Rate of Accel (g/sec)*	*Ignition Delay (sec)*	*No. of Plastic Rods; No. of Pieces*
1750	70	78.1	16.9	176	0.02	5;35
1751	70	78.9	17.2	198	0.03	5;35
1752	160	81.1	18.4	194	0.01	5;35
1753	160	81.5	18.4	182	0.02	5;35
1754	-65	75.1	14.8	168	0.02	5;35
1755	-65	75.0	14.3	142	0.02	5;35
1757	70	82.1	19.6	169	0.01	4;36
1758	70	81.5	19.7	160	0.01	4;36
1759	-65	75.2	16.3	161	0.10	4;36
1760	-65	76.5	15.7	166	0.03	4;36
1761	160	83.6	19.4	180	0.	4;36
1762	160	83.5	20.3	177	0.01	4;36

ACCEPTANCE TESTS
(Rounds 1766 - 1807)

Powder Description

PA Lot	168-2
Powder type	OAC 28-52
Propelled mass	350 lb
Igniter	A1 BP
Magnesium diaphragm	

Performance Data

Round No.	*Velocity (f/s)*	*Init Accel (g)*	*Max Accel (g)*	*Rate of Accel (g/sec)*	*Max Press (psi)*	*Burning Time (sec)*	*Ignition Delay (sec)*
Temperature 70° F							
1766	83.03	0.23	19.3	141	2650	0.24	0.
1767	79.75	0.37	16.8	122	2340	0.26	0.
1768	84.05	0.58	17.9	115	2380	0.25	0.
1769	80.14	1.39	17.5	121	2380	0.22	0.
1770	81.15	0.58	18.2	113	2470	0.25	0.
1791	80.57	0.98	17.8	104	2470	0.26	0.
1792	79.73	1.89	17.0	102	2300	0.26	0.
1793	77.49	0.67	16.1	104	2180	0.26	0.
1794	82.58	1.71	18.7	113	2540	0.26	0.
1795	81.58	0.80	18.2	126	-	0.24	0.
Temperature -65° F							
1771	76.75	1.31	15.3	153	2160	0.23	0.03
1772	78.48	1.46	15.6	136	2210	0.24	0.02
1773	75.66	0.84	15.2	129	2090	0.25	0.02
1774	72.57	0.63	13.2	123	1800	0.25	0.03
1775	73.65	0.30	13.6	120	1910	0.25	0.02
1776	73.50	0.69	13.2	124	1850	0.26	0.03
1777*							
1778	74.89	0.99	13.9	110	1970	0.24	0.03
1779	78.63	0.56	15.9	153	2120	0.24	0.03
1780	74.52	0.33	13.7	149	1910	0.24	0.03

*Primer hit too hard, blocked flash holes. Powder not ignited.

ACCEPTANCE TESTS - (Cont'd)
(Rounds 1766 - 1807)

Performance Data (Cont'd)

Round No.	*Velocity (f/s)*	*Init Accel (g)*	*Max Accel (g)*	*Rate of Accel (g/sec)*	*Max Press (psi)*	*Burning Time (sec)*	*Ignition Delay (sec)*
Temperature 160° F							
1781	84.66	2.08	19.1	162	2590	0.182	0.01
1782	88.53	0.77	23.2	161	3050	0.212	0.01
1783	86.22	2.71	22.2	152	2920	0.21	0.01
1784	86.63	0.77	22.2	182	2920	0.20	0.
1785	84.84	1.12	19.4	149	2600	0.19	0.01
1786	85.33	1.92	20.9	155	2750	0.20	0.01
1787	87.94	1.78	23.1	163	3040	0.21	0.01
1788	90.00	1.83	23.7	168	3110	0.21	0.01
1789	87.89	2.71	21.1	189	2780	0.19	0.01
1790	89.38	1.65	23.1	176	3040	0.20	0.01
Telescopic tube modified. Four slots (0.3 in.^{2}) in bottom							
Temperature 160° F							
1796**	85.14	1.60	20.9	151	2750	0.26	0.
1797	86.27	1.40	22.2	160	2900	0.25	0.
1798	85.98	0.66	20.8	123	2750	0.25	0.01
1799	86.22	0.66	21.5	150	2820	0.25	0.01
1800	87.04	0.29	21.9	159	2800	0.25	0.01
1801	87.30	0.78	22.8	177	2980	0.24	0.015
All aluminum catapults. Most of the inner tubes used were shoulderless. Four slots (0.3 in.^{2}) in bottom of telescopic tube.							
Temperature 160° F							
1802	89.41	0.53	24.9	190	3240	0.235	0.01
1803	84.69	1.43	21.0	180	2760	0.21	0.01
1804	89.31	0.87	19.7	85	2590	0.22	0.01
1805	92.36	0.87	23.7	183	3090	0.24	0.01
1806	90.50	0.87	23.7	183	3140	0.225	0.01
1807	90.03	1.09	24.2	178	3150	0.23	0.015

**Slight gas leak - staking groove and base cap.

CARTRIDGE ACCEPTANCE TEST
(Rounds 1808 - 1817)

Powder Description

PA Lot	168-3
Ignition delay	0.02 sec
Firing temperature	70° F
Vertically fired	Propelled Mass, 350 lb

Performance Data

Round No.	*Velocity (f/s)*	*Init Accel (g)*	*Max Accel (g)*	*Rate of Accel (g/sec)*	*Max Press (psi)*	*Burn Time (sec)*	*Remarks*
1808	78.7	-	-	-	-	-	
1809	79.9	1.0	18.3	112	2420	0.27	
1810	81.4	0.7	19.1	115	2530	0.26	Tight inner tube
1811	80.2	0.3	17.4	112	2350	0.27	
1812	-	1.2	18.9	125	2490	0.25	
1813	83.2	1.2	19.1	119	2510	0.25	
1814	-	0.8	17.6	115	2320	0.19	Steel lock ring removed
1815	82.5	0.5	18.8	128	2550	0.26	Ditto
1816	83.8	1.6	19.0	127	2580	0.25	Ditto
1817	81.8	1.4	18.4	126	2530	0.25	Ditto

CHARGE DEVELOPMENT
(Rounds 1 to 8)
(Using a smaller volume catapult, with a smaller diameter outer tube)

Powder Description

	Rounds 1 to 6	Rounds 7 and 8
Powder	OAC 28-52	HES 5130.12
Outer diameter of grain	0.308	0.361
Web	0.115	0.13
Number of perforations	1	1
Diaphragm	5 mils (magnesium)	
Igniter	65 grains A1 granulation black powder	
MT5 (Modified T5) catapult vertically fired	Propelled mass, 350 lb	
Temperature	70° F	

Performance Data

Round No.	*Powder Charge (gm)*	*No. of Pieces; Length (in.)*	*Velocity (f/s)*	*Max Accel (g)*	*Rate of Accel (g/sec)*	*Init Accel (g)*	*Max Press (psi)*	*Burning Time (sec)*
1	132.7	28; 2.66	88.29	22.1	322	2.0	2900	0.175
2	132.7	28; 2.66	85.83	19.7	259	3.2	2600	0.18
3	107.8	23; 2.66	71.6	13.7	184	2.1	1840	0.21
4	107.9	23; 2.66	67.7	11.6	139	1.9	1580	0.23
5	127.0	26; 2.66	-	19.4	241	3.3	2550	0.18
6	127.0	26; 2.66	79.5	18.3	212	2.4	2410	0.20
7	127.8	20; 2.72	75.1	12.8	136	2.1	2030	0.21
8	127.5	20; 2.72	75.5	13.5	140	2.9	2150	0.20

Investigation of Bursting Pressure of Cartridge, M36

Powder Description

No propellant;
Igniter: First two rounds, 40 grains)
Second two rounds, 50 grains) A1 granulation black powder
Third two rounds, 65 grains)

Results

The only visible effect was a bulging of the cartridge base, which increased with increase in charge. None of the six cases ruptured.

SECTION VI

RESEARCH AND DEVELOPMENT

FOR

WRIGHT AIR DEVELOPMENT CENTER

WEAPONS SYSTEMS DIVISION

DEVELOPMENT OF A PUSH-AWAY DEVICE FOR REMOVAL OF EXTERNAL TANKS ON THE F-101 AIRPLANE
(Project TSI-15-C46)

Project Engineer: A K. Oechsle, Capt., USAF
Ballistics Phase: S. D. Rolle

Authorization: No official authorization received at Frankford Arsenal

OBJECT: To develop and test a push-away device for removal of external tanks on the F-101 Airplane.

STATUS: A letter, dated 23 June 1953, was sent to Frankford Arsenal by Fighter Aircraft Branch, Weapons Systems Division, Wright Air Development Center. The letter stated that McDonnell Aircraft Corporation has the problem of providing a push-away device for removal of external tanks from the F-101 Airplane. The McDonnell Aircraft Corporation has been authorized to contact Frankford Arsenal directly by Weapons Systems Division, Deputy for Operations, Wright Air Development Center.

On 30 June 1953 a job number (C46) was assigned to this task so that preliminary work could be accomplished. An official request for development from the Air Force to the Ordnance Department is required before any work can be started.

SECTION VII

RESEARCH AND DEVELOPMENT

FOR

NAVY DEPARTMENT

BUREAU OF AERONAUTICS
(AE-63)

DEVELOPMENT OF AIRCRAFT PERSONNEL CATAPULT WITH CARTRIDGES
(Project TS1-15-C2)

Project Engineer: R. W. Markgraf
Ballistics Phase: H. A. Sokolowski

Authorization: ORDTS 2-1806, PA 452/114-1, 5 Feb 52

OBJECT: To develop an aircraft personnel catapult with cartridge to satisfy certain performance requirements established by the Department of the Navy.

STATUS: A proposed design for the catapult designated "Catapult, Aircraft Personnel, T15," was approved at a conference of representatives of the Navy Department and Frankford Arsenal on 13 January 1953. The salient features are explained in Figures 57 and 58 and in the following description.

This design required extensive tests of the firing mechanism before it was approved. A firing pin spring was designed to produce a force of 150 pounds. This would retract the latches and fire the primer when the catapult was under a 6800 pound tensile load. This spring requires a 30-pound pull force on the sear pin, but it was felt that this load could be overcome with a mechanical linkage reducing the pull load to 15 pounds.

The trunnion ring supplied by the Navy Department was originally thought to be satisfactory; however, it was found that under the 12,000-pound design load excessive deflection occurred. The ring was strengthened to provide less deflection. Tests of the firing mechanism and trunnion ring are continuing with an aluminum prototype.

The requirement for a safety "blow-out" feature was met by incorporating a tension failure type plug in the base cap. An aluminum alloy has been selected which it was felt should provide the most satisfactory performance. Extensive tests are being programed in order to test the blow-out plug.

A steel catapult is being fabricated. It is intended that this catapult be tested on the tower at Naval Air Equipment Laboratory, Philadelphia Navy Yard, as the Frankford Arsenal tower is incomplete. It is expected that tests will begin in September.

Description. Catapult, Aircraft Personnel, T15, is a three tube, telescoping unit utilizing a mechanical firing system to fire the cartridge. This cartridge is identified as Cartridge, Catapult, T220. Since service requirements specified frequent cartridge removal and the standardized seats (X2 and X3) prevented ready access to the catapult, the head is designed with a pistol grip appendage which extends into the area behind the head rest. The head is fitted with interrupted threads that permit disengagement of the head from the top trunnion and inside tube with a slight amount of rotation.

A system of safety pins and locks is incorporated in the design preventing any possibility of accidental firing. A flight safety pin prevents the crew member from firing the catapult prior to canopy jettisoning. This pin is extracted as the canopy exceeds its normal travel. An identical pin serves as the ground safety. Since the flight safety pin must be removed before the head is lifted out, the ground safety pin should be inserted first. This ground safety pin serves two purposes; it locks the sear in place by engaging a groove in the sear, and second, it permits unlocking of the interrupted threads of the breech by depressing the keeper and clearing the path of the lock.

The pistol grip portion of the head serves as a handle to permit rotation and subsequent extraction of the head and cartridge from the catapult body. Incorporated in the handle is a lock, fashioned as a trigger, that keys the head and trunnion ring interrupted threads against rotation. Thus, to unlock the head and remove it with the cartridge, the ground safety pin is inserted and the flight safety pin extracted. The lock is then triggered and disengaged from its keyhole and the head rotated 45 degrees in a counter-clockwise direction. The head, with the cartridge engaged by its extractor, is then free for withdrawal.

To completely understand the sequence of operations necessary to fire the catapult, an explanation of the mechanical firing system is necessary. The tubes are locked together by a system of latches and pre-cocked firing pin. The latches extend from the head into a groove in the stop ring formed by the interrupted thread undercut. The lock ring, fitting the stop ring interrupted threads, provides the locking surfaces when the catapult supports a tensile load. This lock ring is keyed to the head to prevent misalignment of the threads. The firing pin is restrained in a pre-cocked position by a cage containing three balls. These balls extend from the cage into a groove in the top cavity of the firing pin. A sear rod extending the length of the head handle prevents the balls from becoming disengaged from the firing pin groove. The lower ring of the firing pin engages a recess in the latches, preventing translation of the latches until the firing pin moves a predetermined distance, in this case 1/16 inch.

To fire the catapult for a normal ejection the pilot must first jettison the canopy. The removal of the canopy extracts the flight safety pin, which in effect arms the catapult for firing. Since there are several methods in use for accomplishing the pre-ejection cycle, only the firing of the catapult will be considered. The last portion of the face curtain travel lifts the sear, permitting the three balls in the cage to retract from the firing pin groove. The firing pin, loaded by the firing pin spring, moves downward. The first portion of its travel disengages the lower ring from the latch recesses, permitting these balls to retract. If the catapult tensile load is great enough, the cam angle on the latch locking surfaces will force them to retract. Otherwise, the tapered portion of the firing pin will retract the latches. The last portion of the firing pin drop is considered free fall as it does no work. When it strikes the cartridge primer, the firing pin imparts enough force to fire the primer regardless of any external influence.

Since the latches are fully retracted, the catapult is free to extend its tubes, ejecting the crew member. However, if, because of damage to the seat structure or other external influences, the catapult is restrained from extending its tubes after the cartridge has been fired, a blow-out plug, located in the base cap, will prevent the gas pressures from exceeding a safe level. This blow-out plug is also used as a safeguard in the event of a crash and fire that might cause the cartridge to "cook-off," ejecting the crew member under dangerous conditions.

To prevent the possibility of the aircraft taking off without having the cartridge replaced in the catapult, a telltale or flag is provided. This flag is located in the handle portion of the head and becomes visible only when the cartridge is missing.

Charge Development. **A review of the major ballistics requirements as requested by the US Navy follows.**

Velocity	60 f/s at 70° F
Acceleration	15 g max at 70° F 20 g max at 160° F
Rate of change of acceleration	200 g/sec at 160° F
Propelled mass	330 lb
Temperature range	-65° to 160° F

Various combinations of propellant, igniter charge, method of ignition, case length, etc. were investigated in an attempt to meet the requirements outlined above. In view of the stringent requirements imposed on the Catapult, T15, by limiting the stroke to 50 inches, it was felt that a propellant whose performance was relatively insensitive to temperature and pressure was needed. Such a propellant is HES 5251.3, a member of the double base ABL 1803 plateau family. The powder granulation used in all of the firings had an outside diameter of 0.369 inch with one perforation forming a web thickness of 0.137 inch.

Average results for four rounds containing 90 grams of propellant fired at 70° F are recorded below. The values obtained for rate of change of acceleration are seen to be much larger than the maximum listed in the requirements, while the values obtained for the velocity are lower than the specified minimum.

Igniter A1 BP (gr)	*Propellant No. of Pcs*	*Propellant Length (in.)*	*Velocity (f/s)*	*Acceleration (g)*	*Rate of Change of Acceleration (g/sec)*
40	6	6.0	57.48	14.15	243
40	18	2.0	58.3	14.55	225.5

Several firings were also conducted using a 5-inch flash tube situated in the center of the 90-gram powder charge. In addition to the normal configuration of holes on the lateral surface of the tube, a hole was drilled in the lower end. No appreciable change in results was noticeable at a temperature of 70° F.

Hole Dia (in.)	Igniter Al BP (gr)	Propellant No. of Pcs	Propellant Length (in.)	Velocity (f/s)	Acceleration (g)	Rate of Change of Acceleration (g/sec)
none	50	6	6.0	58.04	14.45	230
1/8	30	6	6.0	57.49	15.95	247
1/8	30	9	4.0	56.70	14.30	218

Plastic rods, 3/8 inch in diameter, were introduced into the cartridge to occupy volume so that a minimum amount of propellant would be required to build up the bursting pressure. The flash tube, containing 30 grains Al BP were used on these firings. Temperature was 70° F for all shots.

The results of using the plastic rods are as follows.

Hole Dia (in.)	No. of Rods	Propellant No. of Pcs	Propellant Length (in.)	Propellant Weight (gm)	Velocity (f/s)	Acceleration (g)	Rate of Change of Acceleration (g/sec)
none	3	7	5.15	90.0	59.62	14.6	160
1/4	3	7	5.15	90.0	62.36	17.1	301
none	4	6	5.15	77.0	52.53	13.4	156
1/8	3	7	5.15	90.0	59.15	15.8	253

In view of the above, only the first test with 90.0 grams of propellant and three plastic rods indicated a useful charge. However, to investigate the addition of inert inserts more thoroughly, with a view toward eliminating them by utilizing a shorter case length, additional rounds were fired. The first group of data to be compared was obtained from rounds fired in a six inch case. Performance vs quantity of igniter will be compared. A second group of rounds fired in annealed six inch cases allows the effect of soft cases to be studied. It was supposed that soft cases would allow low rupture pressures and lead to lower rates of change of acceleration. Conditions that were held constant are as follows:

Propellant weight	90 grams
Number of pieces	7
Length	5.15 inches
Temperature	70° F

Ignition was accomplished by the use of flash tubes, with three rounds fired in each igniter weight.

Normal Cartridge with Three Plastic Rods

Igniter A1 BP (gr)	Average Velocity (f/s)	Average Acceleration (g)	Average Rate of Change of Acceleration (g/sec)
30	60.04	14.6	247
60	60.21	14.4	206
90	61.16	15.7	256

Normal Cartridge without Plastic Rods

Igniter A1 BP (gr)	Average Velocity (f/s)	Average Acceleration (g)	Average Rate of Change of Acceleration (g/sec)
30	61.51	16.3	260
60	63.61	16.5	268
90	62.10	16.4	232

It would seem that there is no great improvement with the change in igniter weight. However, the rate of change of acceleration does vary widely; the best performance is evidenced in the 60 grain A1 BP group with the plastic rods.

Annealed Cartridge with Three Plastic Rods

Igniter A1 BP (gr)	Average Velocity (f/s)	Average Acceleration (g)	Average Rate of Change of Acceleration (g/sec)
30	59.85	14.5	178
60	60.69	15.7	220
90	58.23	15.3	204

Annealed Cartridge without Plastic Rods

Igniter Al BP (gr)	*Average Velocity (f/s)*	*Average Acceleration (g)*	*Average Rate of Change of Acceleration (g/sec)*
30	59.88	16.9	232
60	60.98	18.2	287
90	61.14	16.6	272

In this group it appears that there is no great difference in performance for various igniter weights. The most acceptable performance in either of the cases would seem to be with 30 grains Al BP. However, with no plastic rods, the acceleration and rate of change of acceleration were high, though nearer to the specifications than the others. It would appear from these and previous firings that the performance benefits of the addition of plastic rods to increase the loading density of the cartridge are worthy of further study. It is difficult to appreciate the effect on performance of the annealed case. In general, its use resulted in lower values for velocity, acceleration, and rate of change of acceleration. It was seen that the cartridges containing the three plastic rods in the annealed case gave the best results for all igniters listed above.

In the following firings the initial burning surface of the propellant was restricted with a wrapping of scotch tape.

Powder Surface Exposed (sq in.)	*Average Velocity (f/s)*	*Average Acceleration (g)*	*Average Rate of Change of Acceleration (g/sec)*
54.0	56.56	14.4	221
45.8	58.99	14.1	219
37.7	57.59	12.6	203

This type of surface restriction shows no marked improvement over earlier performance.

In the following group of firings a case with a cardboard bottom was used to give low bursting pressure. No inserts were used.

Temperature	70° F
Ignition	Flash tube and 60 gr Al BP
Propellant weight	90 grams
Number of pieces	7
Length	5.15 inches
Grain restriction	as noted

Powder Surface Exposed (sq in.)	*Case Bottom*	*Average Velocity (f/s)*	*Average Acceleration (g)*	*Average Rate of Change of Acceleration (g/sec)*
45.8	Cardboard	56.94	13.7	187
45.8	Normal	57.35	13.4	187
37.7	Cardboard	53.66	12.7	134
37.7	Normal	55.44	14.6	135
none	Cardboard	59.00	14.9	237
none	Normal	63.61	16.5	268

A feature of the above data is that there seems to be little difference in the performance between the cardboard bottom and the normal bottom cartridges. The effect of powder restriction, however, is noticeable, contrary to earlier firings.

To determine the effect of elevated temperatures (160° F) on a case with a cardboard bottom, several firings were made. The propellent charge was identical to other similar shots, with the exception of grain restriction and a 30 grain Al BP igniter.

Average velocity	62.9 f/s
Average acceleration	17.4 g
Average rate of change of acceleration	290 g/sec

Tests were conducted in which the propellant was contained in a small rocket motor instead of a cartridge case. Limited firings indicated that this ballistic design did not lend itself to adoption in Cartridge, T220.

Firings were made in which the plastic rods were replaced by aluminum rods. It was hoped that the aluminum rods would not only occupy volume, but would also absorb some of the initial propellent energy, thus giving a lower rate of change of acceleration.

Filler	*Average Velocity (f/s)*	*Average Acceleration (g)*	*Average Rate of Change of Acceleration (g/sec)*
Aluminum rods	59.10	14.9	190
Plastic rods	60.04	14.6	247
None	63.61	16.5	268

It is readily noted that the aluminum rods give the most satisfactory conformance to the specifications.

A series of tests to determine whether shortening the case to reduce the free volume would result in performance similar to that obtained with other reduced volumes caused by insertion of inert materials. Data are reported below. However, analysis is difficult because the grain geometry had to be altered to fit the shorter case.

Temperature	70° F
Igniter charge	30 grains Al BP
Propellant weight	90 grams

Case Length (in.)	*Igniter*	*Propellant*		*Average Velocity (f/s)*	*Average Acceleration (g)*	*Average Rate of Change of Acceleration (g/sec)*
		No. of Pcs	*Length (in.)*			
4.5	5 mil	10	3.62	63.81	19.7	268
6.0	Mg disc	7	5.15	57.46	14.1	197
4.5	flash	10	3.62	61.43	17.9	260
6.0	tube	7	5.15	56.59	14.4	221

Apparently, because of the larger grain surface in the shorter case the propellant was consumed more rapidly. This led to higher velocity, acceleration, and rate of change of acceleration. In no firing did the shorter case give as good performance as that obtained with the longer case and inert inserts.

Firings comparing short cases, both annealed and normal, were tried. Results were erratic and outside requirements. In summary, the following can be said.

In all but a few firings the rate of change of acceleration was too large Frequently the velocity was too low. The addition of aluminum rods as a case filler seemed to give the best results. Several additional powders are on order for a wider approach to the problem. It is hoped that these powders, in a short case, will give satisfactory results. Detailed firing record is presented in Table V.

Neg. #24498-62
R-1183

Table 7. Catapult, T15, Firing Record

	Date Fired	Round No.	Propellant Weight (gm)	Propellant No. of Pieces	Propellant Length (inches)	Igniter Al:BP (gr)	Flash Tube	5 Mil Mg Disc	Temp (°F)	Velocity (f/s)	Initial Acceleration (g)	Acceleration (g)	Rate of Change of Acceleration (g/sec)	Max Pressure (lb/sq in.)	Ignition Delay (sec)	Burning Time (sec)	Weight of Propelled Mass (lb)
	1/28	27	90.2	6	6.0	40.0		x	70	58.33		14.1	248	1590	0	0.173	350
	1/28	28	90.2	6	6.0	40.0		x	70	57.05		14.2	238	1580	0	0.175	
	2/2	29	90.0	18	2.0	40.0		x	70	58.18 57.76		14.1	217	1520	0	0.17	
	2/2	30	90.0	18	2.0	40.0		x	70	58.84 58.40		15.0	234	1620	0	0.163	
	2/3	31	90.0	6	6.0	30.0		x	70	57.16 57.64		14.2	215	1570	0.02	0.15	
	2/3	32	90.0	6	6.0	30.0		x	70	58.50 58.84		14.7	245	1630	0	0.16	
	2/5	33	90.0	6	6.0	30.0		x	70	58.40 57.66		17.6	262	1880	0.03	0.14	
	2/6	34	90.0	9	4.0	30.0		x	70	56.70		14.3	218	1560	0	0.17	325
	2/6	35	90.0	6	6.0	30.0	x		70	57.70 56.20		14.3	232	1540	0	0.17	
	2/10	36	90.0	7	5.15	30.0	x		70	59.62		14.6	140	1410	0.04	0.17	
	2/10	37	90.3	7	5.15	30.0	x		70	59.83		15.4	299	1570	0.085	0.15	
	2/10	38	90.0	7	5.15	30.0	x		70	58.80 58.47					0.065	0.155	
	2/10	39	77.0	6	5.15	30.0	x		70	54.30 53.78					0.05	0.17	
	2/13	40	90.0	7	5.15	30.0	x		70	49.90 52.06							
	2/16	41	90.3	7	5.15	30.0	x		70	57.58 59.38		16.2	247	1690	0.045	0.155	
	2/16	42	90.3	7	5.15	30.0	x		70	62.05 62.67		17.1	301	1720	0	0.16	
	2/16	43	77.0	6	5.15	30.0	x		70	51.05 54.02		13.4	156	1420	0.06	0.17	
	3/26	44	90.0	7	5.15	30.0	x		70	60.02 60.54		15.5	230	1650	0.02	0.141	
	3/26	45	90.0	7	5.15	30.0	x		70	62.22 62.60		17.2	240	1650	0.015	0.195	
*										61.40		16.3	235	1650	0.018		
	3/26	46	90.0	7	5.15	60.0	x		70	63.10 63.61		16.3	257	1620	0	0.15	
	3/26	47	90.0	7	5.15	60.0	x		70	63.71 63.50		16.6	279	1610	0	0.151	
*												16.5	262	1615	0		
	3/26	48	90.0	7	5.15	80.0	x		70	59.99 60.21		15.7	204	1540	0	0.158	
	3/26	49	90.0	7	5.15	80.0	x		70	65.72 63.69		17.1	299	1640	0	0.15	
*										62.4		16.4	232	1590	0		
	3/30	50	90.0	7	5.15	30.0	x		70	63.05 63.54		14.8	277	1580	0	0.155	
	3/30	51	90.0	7	5.15	30.0	x		70	59.00 58.99		14.4	218	1500	0	0.16	
*										61.1		14.6	248	1540	0		
	3/30	52	90.0	7	5.15	60.0	x		70	60.01 60.33		15.0	203	1580	0	0.162	
	3/30	53	90.0	7	5.15	60.0	x		70	60.30		13.9	209	1450	0	0.161	
*										60.2		14.5	206	1520	0		
	3/30	54	90.0	7	5.15	80.0	x		70	60.77 61.29		16.3	272	1580	0	0.151	
	3/30	55	90.0	7	5.15	80.0	x		70	60.75 61.21		15.0	240	1590	0	0.157	
*										61.0		15.7	256	1575	0		
	4/3	56	90.0	7	5.15	30.0	x		70	60.10 60.76		16.9	247	1660	0	0.168	
	4/3	57	90.0	7	5.15	30.0	x		70	58.79 59.19		16.9	216	1620	0	0.175	
*										59.7		16.9	232	1640	0		
	4/3	58	90.0	7	5.15	60.0	x		70	60.18 60.69		17.9	276	1710	0	0.167	
	4/3	59	90.0	7	5.15	60.0	x		70	61.46		18.5	298	1770	0	0.166	
*										60.8		18.2	287	1760	0		
	4/6	60	90.0	7	5.15	80.0	x		70			16.7		1600	0		
	4/6	61	90.0	7	5.15	80.0	x		70	60.94 61.43		16.5	272	1630	0	0.167	
*										61.1		16.6	272	1615	0		
	4/8	62	90.0	7	5.15	30.0	x		70	59.61 60.02							
**	4/8	63	90.0	7	5.15	30.0	x		70	59.23 59.84		14.5	178	1500	0	0.214	
*										59.7		14.5	178	1500	0		
**	4/8	64	90.0	7	5.15	60.0	x		70	62.33		16.5	253	1620	0	0.185	
**	4/8	65	90.0	7	5.15	60.0	x		70	59.32 59.44		14.9	187	1480	0	0.185	
*										60.4		15.7	220	1550	0		
**	4/8	66	90.0	7	5.15	80.0	x		70	57.44		15.5	196	1590	0	0.183	
**	4/8	67	90.0	7	5.15	80.0	x		70	59.82 58.66		15.1	212	1530	0	0.192	
*										58.6		15.3	204	1560	0		
	4/15	68	90.0	7	5.15	30.0		x	70	56.12 58.48	1.9	14.4	187	1530	0.02	0.16	
	4/15	69	90.0	7	5.15	30.0		x	70	56.65 56.90	1.1	13.7	206	1450	0.02	0.165	
*										57.0	1.5	14.1	197	1490	0.02		
	4/15	70	90.0	7	5.15	30.0	x		70	57.77 58.34	1.4	14.5	224	1500	0.02	0.16	
	4/15	71	90.0	7	5.15	30.0	x		70	55.12 54.86	1.1	14.3	218	1440	0.01	0.17	
*										56.5	1.3	14.4	221	1470	0.015		
	4/15	72	90.0	7	5.15	30.0	x		70	59.26 59.24	1.6	14.3	231	1520	0.03	0.18	
	4/15	73	90.0	7	5.15	30.0	x		70	59.42 58.62	0.8	13.9	207	1520	0.03	0.18	
*							x		70	59.1	1.2	14.1	219	1515	0.03		
	4/15	74	90.0	7	5.15	30.0	x		70	58.42 59.18					4.00		
	4/15	75	90.0	7	5.15	30.0	x		70	57.86 55.80	0.4	12.6	203	1390	3.86	0.17	
*										57.8	0.4	12.6	203	1390			

* Average of two preceding firings
** Cartridge contained plastic rods

Surface Restriction
Rounds 68 & 69, 54 sq in.
[illegible] & [illegible], 46.8 sq in.
74 & 75, 39.7 sq in.

Propellant - [illegible] 5251.3
OD - 0.369 in.
Web - 0.137 in.
No. of Perf. - 1

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Table V. Catapult, T15, Firing Record (Cont'd)

	Date Fired	Round No.	Propellant Weight (gm)	No. of Pieces	Length (inches)	Igniter Al BP (gr)	Flash Tube	5 Mil Mo Disc	Temp (°F)	Velocity (f/s)	Initial Acceleration (g)	Acceleration (g)	Rate of Change of Acceleration (g/ms)	Max Pressure (lb/sq in.)	Ignition Delay (ms)	Burning Time (sec)	Weight of Propelled Mass (lb)
	5/1	76	90.0	7	5.15	30.0	x		70	58.93	0	15.0	248	1500	0.05	0.17	325
										59.51							
	5/1	77	90.0	7	5.15	30.0	x		70	58.69	0	14.8	285	1470	0.085	0.17	
										58.91							
*										59.0	0	14.9	237	1485	0.065 4.0		
	5/1	78	90.0	5	7.25	30.0		x	70	63.26							
										68.27							
	5/1	79	90.0	5	7.25	30.0		x	70	69.32	0	30.6	438	2080	0	0.13	
*										69.1	0	30.6	438	2080			
**	5/11	80	90.0	7	5.15	30.0		x	160	61.1	0	17.3	298	1690	0	0.15	
**	5/11	81	90.0	7	5.15	30.0		x	160	58.2	0	16.0	234	1620	0.01	0.15	
*										59.7	0	16.7	266	1645			
	5/11	82	90.0	7	5.15	30.0	x		160	62.2	0	17.3	286				
										63.1							
	5/11	83	90.0	7	5.15	30.0	x		160	62.9	0	17.5	296				
										63.1							
*										62.9	0	17.4	290				
***	5/25	84	90.0	7	5.15	30.0	x		70	59.1	1.6	15.3	198	1500	0.015	0.16	
***	5/25	85	90.2	7	5.15	30.0	x		70		1.3	14.4	182	1460	0.04	0.16	
*									70	59.1	1.5	14.9	190	1480			
***	5/25	86	90.3	7	5.15	60.0	x		70		2.6	15.1	189	1540	0.01	0.16	
***	5/25	87	90.3	7	5.15	60.0	x		70		2.5	15.8	197	1550	0.01	0.16	
*											2.6	15.5	194	1545	0.01		
	5/28	88	90.2	7	5.15	60.0	x		70	56.47							
										56.76							
	5/28	89	90.3	7	5.15	60.0	x		70	57.14	0	13.7	187	1390	0	0.20	
*										56.96	0	13.7	187	1390			
	5/28	90	90.3	7	5.15	60.0	x		70	52.10	0	12.7	135	1330	0	0.23	
										53.92							
	5/28	91	90.2	7	5.15	60.0	x		70	52.86	0	12.7	133	1300	0	0.23	
										53.39							
*										53.66	0	12.7	134	1315			
	5/28	92	90.3	7	5.15	60.0	x		70	58.51	2.2	13.2	192	1320	0	0.18	
										57.30							
	5/28	93	90.2	7	5.15	60.0	x		70	57.01	2.0	13.6	181	1380	0	0.18	
										57.19							
	5/28	94	90.2	7	5.15	60.0	x		70	53.77							
	5/28	95	90.3	7	5.15	60.0	x		70	55.09	2.4	14.6	135	1490	0	0.20	
										55.44							
	6/19	96	90.0	10	3.62	30.0		x	70	61.96	4.07	18.7	273	1790	0	0.165	
	6/19	97	90.0	10	3.62	30.0		x	70	63.83	1.43	20.7	263	1960	0	0.158	
										65.65							
	6/19	98	90.0	10	3.62	30.0	x		70	62.60	1.95	19.0	290	1810			
										63.82							
	6/19	99	90.0	10	3.62	30.0	x		70	59.06	2.29	16.9	230	1630	0	0.167	
	6/26	102	85.0	10	3.42	30.0		x	70	60.93	0.95	17.7	253	1700	0	0.17	
										61.44							
	6/26	103	85.0	10	3.42	30.0		x	70	60.38	0.79	16.7	237	1610	0	0.17	
										60.86							
	6/19	100	90.0	10	3.62	65.0		x	70	55.97	0	11.6	299		0	0.16	
										57.75							
	6/19	101	90.0	10	3.62	65.0		x	70	60.39	0	16.3		1400	0	0.15	
										61.72							
	6/26	104	85.0	10	3.42	30.0		x	70	59.27	1.80	15.6	222	1560	0.02	0.16	
										57.07							
T	6/26	105	85.0	10	3.42	30.0		x	70	57.09	1.43	15.4	205	1510	0.04	0.17	
	6/26	106	90.0	10	3.62	45.0	x		70	65.34	1.19	17.9	261	1720	0	0.17	
	6/26	107	90.0	10	3.62	45.0	x		70		0.99	17.9	287	1720	0	0.16	
	6/26	108	90.0	10	3.62	45.0	x		70		2.48	16.2	235	1880	0	0.16	
	6/26	109	90.0	10	3.62	45.0	x		70	62.24	1.88	17.5	253	1800	0	0.16	
										63.03							

* Average of two preceding firings
** Cartridge contained plastic rods
*** Cartridge contained aluminum rods

Case Bottom
Rounds 76 & 77, Cardboard insert

Surface Restriction
Rounds 88 & 89, 45.8 sq in., Cardboard Bottom
Rounds 90 & 91, 37.7 sq in., Cardboard Bottom
Rounds 92 & 93, 45.8 sq in.
Round 94 57.7 sq in.

Rocket Motor
Rounds 78 & 79, [illegible]

Propellant - [illegible] 5251.3
OD - 0.369 in.
Web - 0.137 in.
No. of Perf. - 1

SECTION VIII

TABULATIONS

PERFORMANCE CURRENT CAD ITEMS

Neg #24498-64
R-1183

CATAPULT PERFORMANCE DATA

Catapult	Cartridge	Temp (°F)	Velocity (f/s) Specified	Velocity (f/s) Actual	Acceleration (g) Specified Max	Acceleration (g) Actual	Rate of Acceleration (g/s) Specified Max	Rate of Acceleration (g/s) Actual	Propellant Lot	Propellant Type	Propellant Mass (gm)
M1A1(T4E2) M5(T4E4)	M26A1	-65	45	51.2	13	9.5	250	43	10W 6030	M6	84.5
		70	60	62.0	18	14.4	170	95	10W 6030	M6	84.5
		160	67	69.3	20	19.1	250	160	10W 6030	M6	84.5
M2A1	M30A1	70	45	48.7	12	10.4	150	80	10W 6030	M6	77
M3(T5E4)	M36(T109E2)	-65	70	76.9	18.5	13.8	250	111	NBS 5130.14	M8	200
		70	77	81.3	18.5	16.5	170	105	NBS 5130.14	M8	200
		160	84	87.2	20	19.9	250	178	NBS 5130.14	M8	200
M4(T9E3)	M37	-65	33	38.9	10.5	7.3	125	82	NBS 5130.16	M8	55
		70	38	40.3	10.5	7.7	100	56	NBS 5130.16	M8	55
		160	42	46.6	12	11.3	125	104	NBS 5130.16	M8	55
	T123E1	-65	33	36.8	10.5	6.4	125	40	5130.6B	M8	58.5
		70	38	40.9	10.5	8.1	100	58	98	T2	7.7
		160	42	45.2	12	10.6	125	81			
	T123E2	-65	-	31.3	-	4.0	-	30	5130.6B	M8	58.5
		70	-	32.6	-	5.0	-	25	98	T2	7.7
		100	-	35.2	-	5.6	-	29			
T10	T125	-65	-	65.1	-	13.3	-	142	PA-E 8437	T8	160
		70	-	70.7	-	16.2	-	100	PA-E 8437	T8	160
		160	70	77.5	20	20.0	200	168	PA-E 8437	T8	160
T13E2**	T127	-65			50		No requirement			M2	
		70			50		No requirement			M2	
		160			50		No requirement			M2	
T14E1*	T157	70	30	26.8	10	8.6	125	134	NBS 4831.11	M2	28
T15	T220	-65									
		70	60								
		160			20						
T16***	T226	-65	44		12		125				
		70			12		125				
		160			12		125				

Catapult	Cartridge	Igniter Black Powder Mass (gr)	Igniter Black Powder Granulation	Propelled Mass (lb) Specified	Propelled Mass (lb) Actual	Stroke (in.) Tel	Stroke (in.) Inner	Overall Length (in.)	Area (sq in.) Tel	Area (sq in.) Inner	Initial Volume (cu in.)	Weight of Total Assembly (lb)	Service Material
M1A1(T4E2) M5(T4E4)	M26A1	65	A1	300	312	31.5	34.5	39.4	2.86	2.415	78	8.1	Aluminum
M2A1	M30A1	50	A1	300	311.8	26.	34.	39.	3.125	2.39	81	13.	Steel
M3(T5E4)	M36(T109E2)	65	A1	350	365.2	43.3	45.3	50.5	2.918	2.426	226	22.	Alum. & Steel
M4(T9E3)	M37	50	A4	325	324.	21.25	23.69	30.8	2.27	1.77	70	6.1	Aluminum
M4(T9E3)	T123E1	55	A4	425	421.	21.25	23.69	30.8	2.27	1.77	70	6.1	Aluminum
M4(T9E3)	T123E2	55	A4	325	324.	21.25	23.69	30.8	2.27	1.77	70	6.1	Aluminum
T10	T125	65	A1	350	363.4	33.56	38.44	45.8	3.733	3.142	176	16.	Alum. & Steel
T13E2**	T127				45.	11.5	12.	16.	2.41	1.78			Alum.
T14E1*	T157	25	A1	300	300		21	39.6		1.77	24	31.5	Steel
T15	T220			390	340								Alum.
T16***	T226			800		76		42.3					Alum.

*Indoctrination catapult
** Beacon launcher
*** Dual catapult

Neg. #24498-65
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REMOVER PERFORMANCE DATA

Remover	Cartridge	Temp (°F)	Velocity (f/s) Specified Min	Velocity Specified Max	Velocity Actual	Thrust (lb) Specified Min	Thrust Specified Max	Thrust Actual	Propellant Lot	Propellant Type	Propellant Mass (gm)	Igniter Black Powder Mass (gr)	Igniter Black Powder Granulation
[illegible] M1A1*(T[illegible])	M[illegible](T160)	-65	20		24.0	2000		2320	[illegible] A631.9	M[illegible]	7.8	25	AA
		70	28		27.3	2800	3800	3110					
		160		30	28.4		5200	3700					
M1A2*		-65	20		24.2	2000		2880	MPC Lot 1	M[illegible]	7.0	25	AA
		70	28		27.3	2800	3800	3370					
		160		30	28.9		5200	4180					
M3A1(T6)	M[illegible]	-65	20		24.0	2000		2550	AL [illegible]	M[illegible]	23	25	A1
		70	23		25.7	2600	3400	2890					
		160		29	26.5		4800	2930					
M3(T[illegible]) (T[illegible])***		-65	20		24.5	2000		2710	[illegible]	M[illegible]	23	25	A1
		70	23		26.3	2600	3400	3160					
		160		29	27.2		4800	3480					

Remover	Cartridge	Propellant Mass (lb) [illegible]	Propellant Mass Actual	Stroke (in.) [illegible]	Stroke [illegible]	Overall Length (in.)	Area (sq in.) [illegible]	Area [illegible]	Initial Volume (cu in.)	Weight of Total Assembly (lb)	Service Material
[illegible] M1A1*(T[illegible]) M1A2*	M[illegible](T160)	300	311.1	11.5	12	16	2.41	1.78	18	2.2	Alum.
M3A1(T6) M3(T[illegible]) (T[illegible])***	[illegible]1A1	300	312.2	-	20.25	30.0		1.98	74	4.4	Alum.

*[illegible] M[illegible](T[illegible]) [illegible] (a [illegible] of 200 psi will [illegible] the [illegible] rod into the [illegible] body)
**[illegible] version [illegible]
***[illegible] version of M3

THRUSTER PERFORMANCE DATA

Thruster	Cartridge	Thrust (lb) Specified Initial	Thrust Specified Final	Thrust Average Initial	Thrust Average Final	Stroke (in.)	Propellant Lot	Propellant Type	Propellant Mass (gm)	Black Powder Booster Granulation	Black Powder Booster Mass (gm)	Propelled Mass (lb)**	Piston Area (in.²)	Initial Volume (in.³)	Weight of unit (lb)*	Outside Dimensions Length (in.)	Outside Dimensions Diameter (in.)
M-5(T[illegible])	M-[illegible]					5.0							1.0		3.[illegible] ± 0.08	11.437 + 0.030 - 0.[illegible]	1 1/2
T-6	T[illegible]	400				1.5	5130.12	M[illegible]	2.1	AA	1.2	60	0.196	0.066			
T-9		2500				5.7	[illegible]	M[illegible]	3	AA	1.0	20	1.23	5.5		12.6	2.0
T-7		9-2700				13.3						[illegible]					
T-8		9-2700				9.6						[illegible]					
T181	T161					2.0		M[illegible]		AA			1.0	1.304		9.9	1.8
T[illegible]	T162					5.7		[illegible]		AA			1.0			13.7	1.8
M-3(T[illegible])	T163[illegible]					1.5		M[illegible]		AA			0.30	1.152	1.80 ± 0.05	8.071 -0.0[illegible]	1 1/16
M-4(T[illegible])	T164					5.0		M[illegible]		AA			1.0	1.304		20.6	1.5

*[illegible] data
**Excluding piston

Neg. #24498-66
R-1183

INITIATOR PERFORMANCE DATA

		Pressure at End of Tubing				Propellant			Black Powder Booster	
Initiator	Cartridge	Tubing	Length (ft)	Temp (°F)	Pressure (psi)	Lot	Type	Mass (gm)	Granulation	Mass (gm)
M3(T4)/M5(T5)	M38(T129)	Type A	4	-65	2960	5280	M2	2.8	A4	1.0
				70	3190					
				160	3250					
			15	-65	1000					
				70	1190					
				160	1225					
			21	-65	790					
				70	770					
				160	800					
T8**	T209					4831.9	M2	12.3	A4	1.0
T10	T214*					KEN A258	M2	0.2	A4	0.25
M6(T13)/M4(T14)	M46(T217)	Type A	3	-65	2185	MPC A262	M2	1.6	A4	1.0
				70	2400					
				160	2400					
		Type A**	1	-65	1255					
		Type B	2	70	1460					
				160	1520					
T12	T210									
T16 3-sec delay	T231					RAD 477	M2	4	A4	1.0
T17										
T19	T234					RAD 477	M2	4	A4	1.0

*T213 cartridge will give same performance
**Type A: Flexible hose AN-H -24 size 4
Type B: Stainless steel 0.25 in. OD x 0.028 in. wall

NOTE: There are also in existence three other initiators, T1, T2, and T3, on which no data are available.

FIGURES

Neg. #24498-1
R-1183

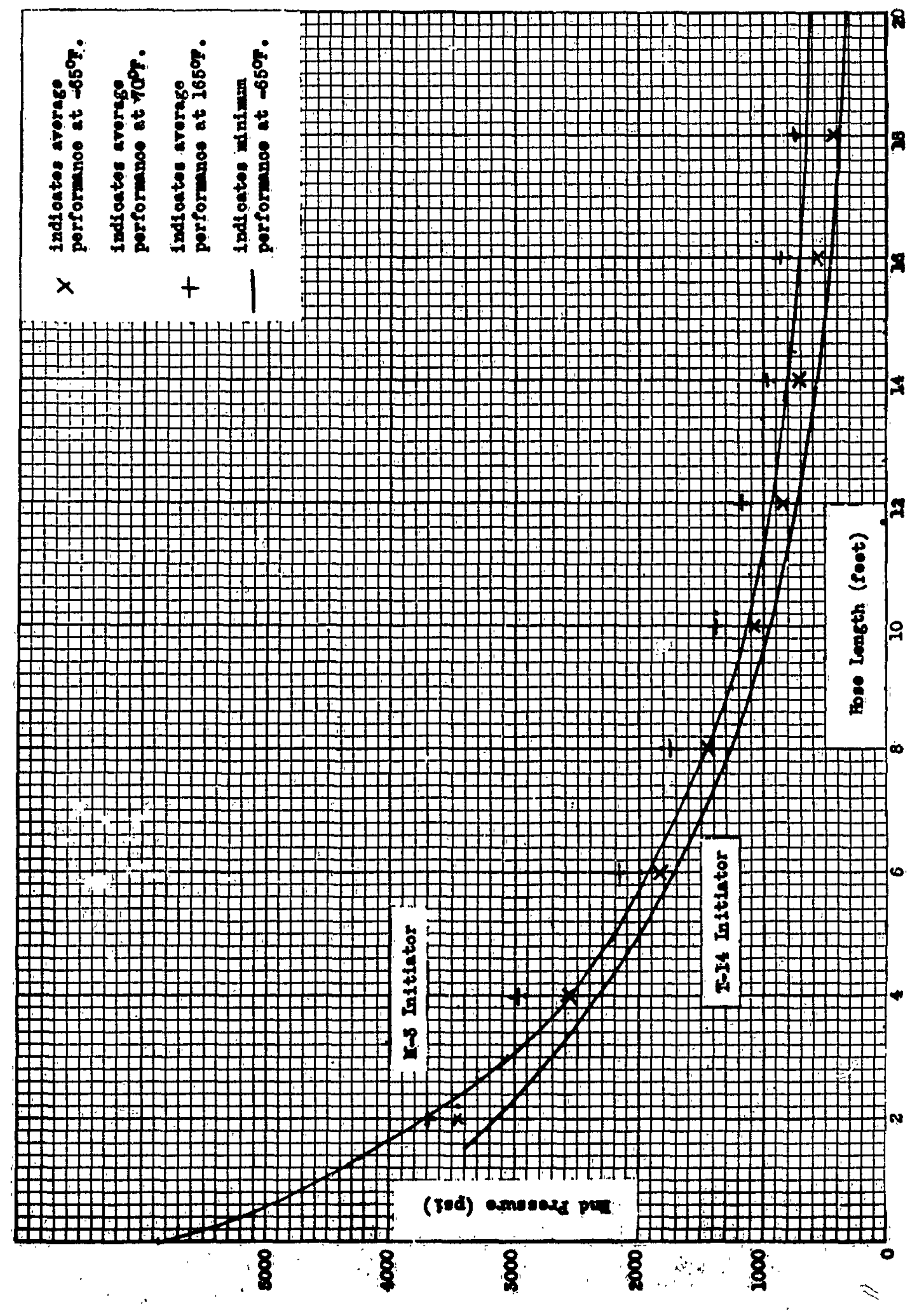
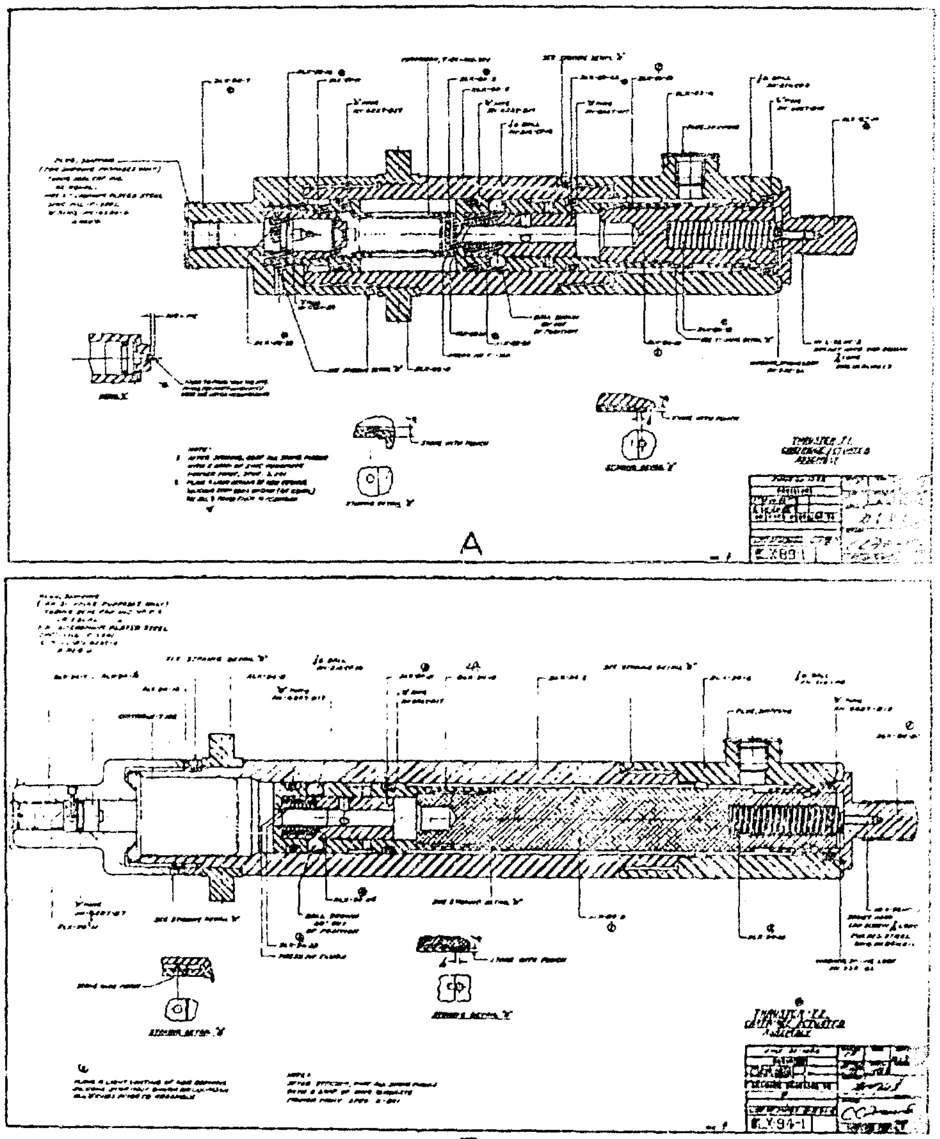


Figure 1. End pressure vs hose length, Initiator, M3, and Delay-Initiator, T14

Neg. #24493-2
R-1183

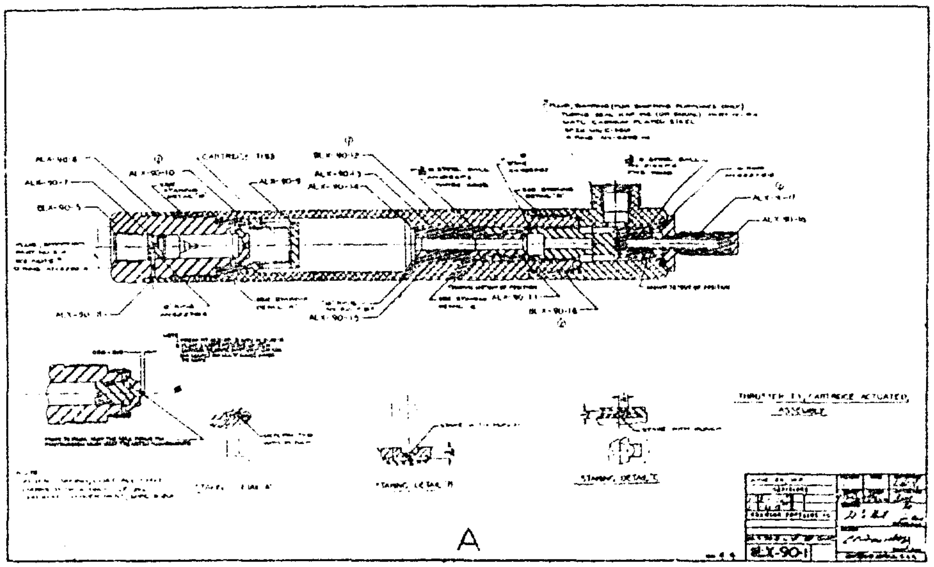


A

B

Figure 2. A - Thruster, T1
B - Thruster, T2

Neg. #24498-3
R-1183



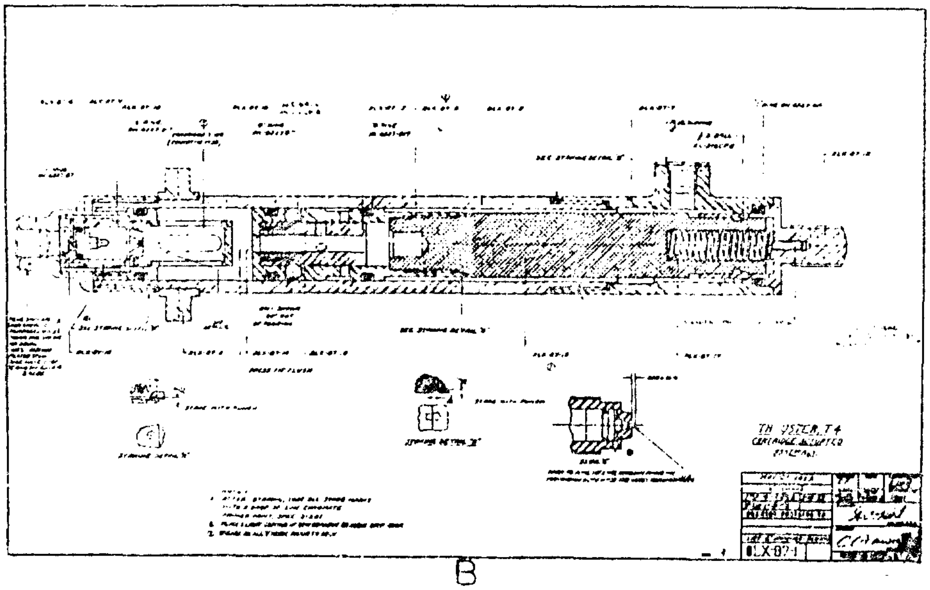


Figure 3. A - Thruster, T3
B - Thruster, T4

Neg #24498-4
R-1183

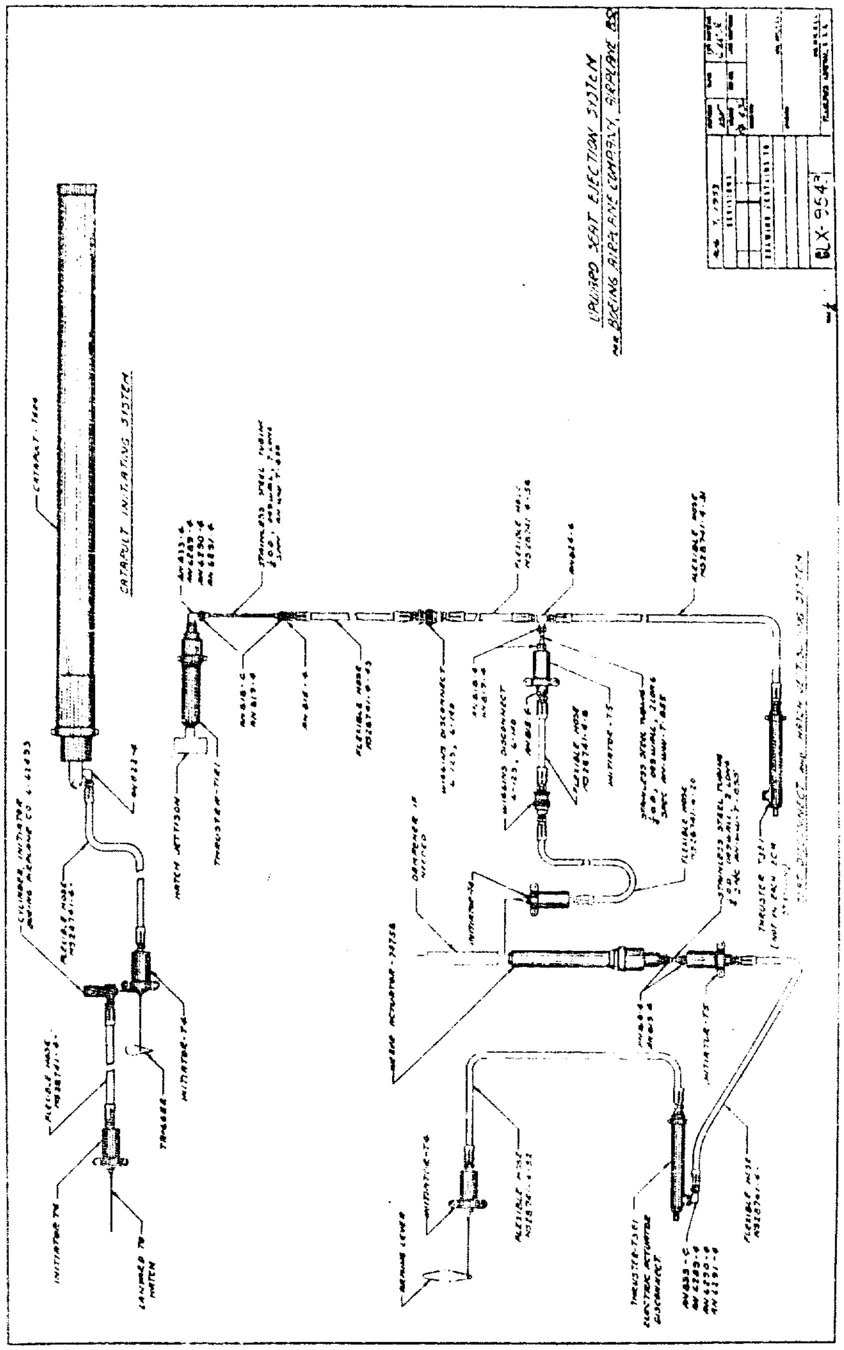


Figure 4. Upward seat ejection system

Neg. #24498-5
R-1183

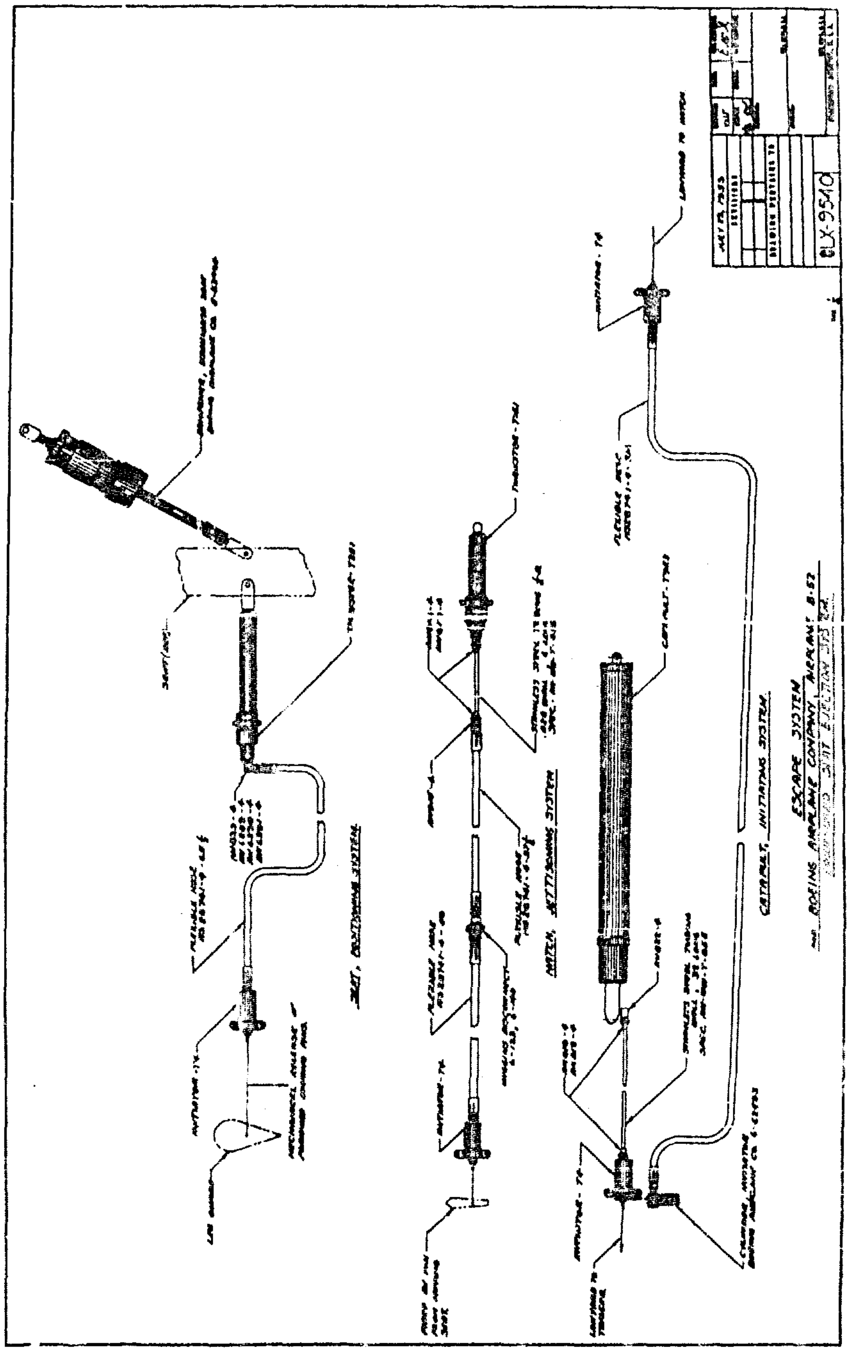


Figure 5. Downward seat ejection system for B-52 Airplane

Neg. #24498-6
R-1183

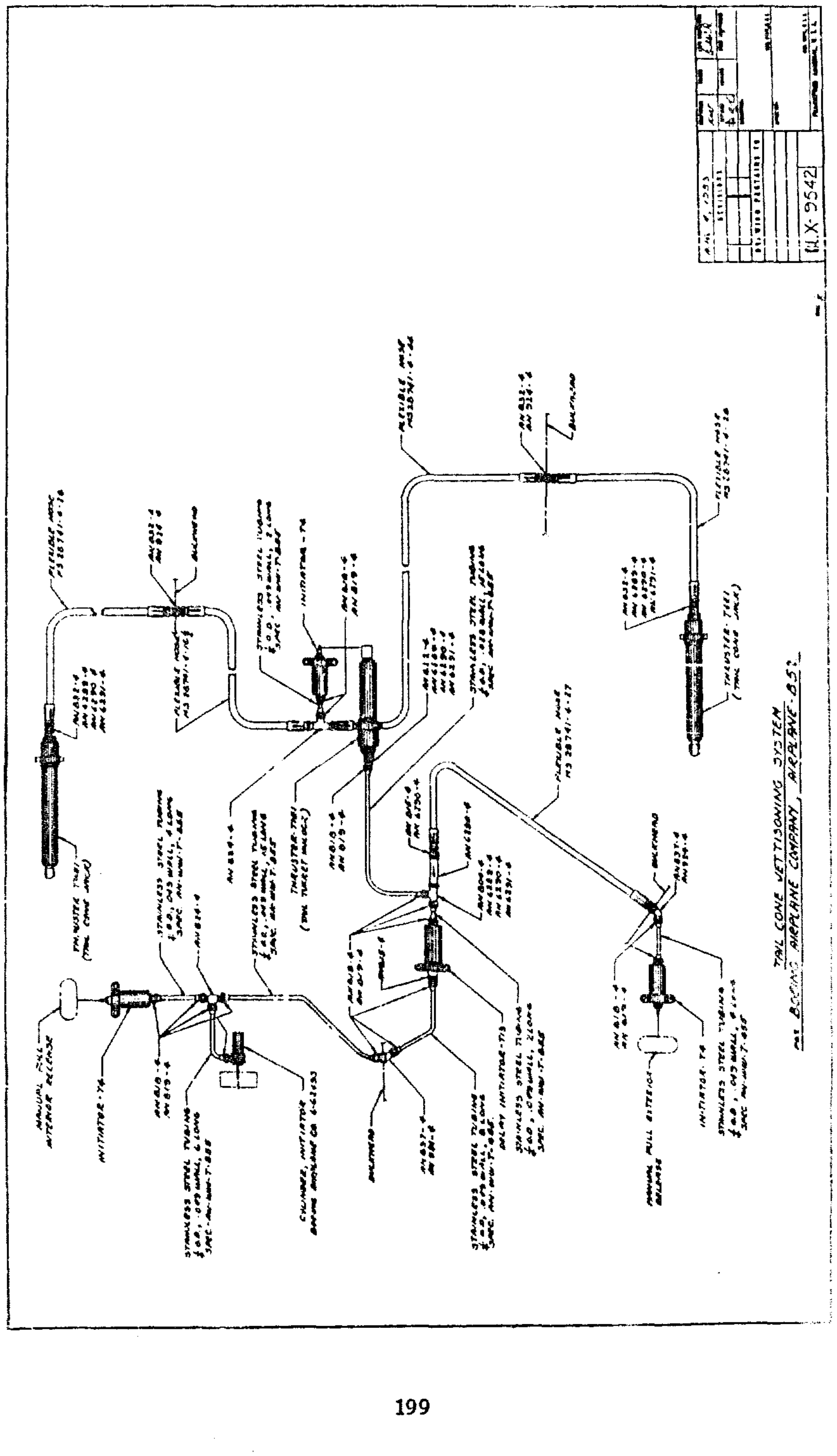
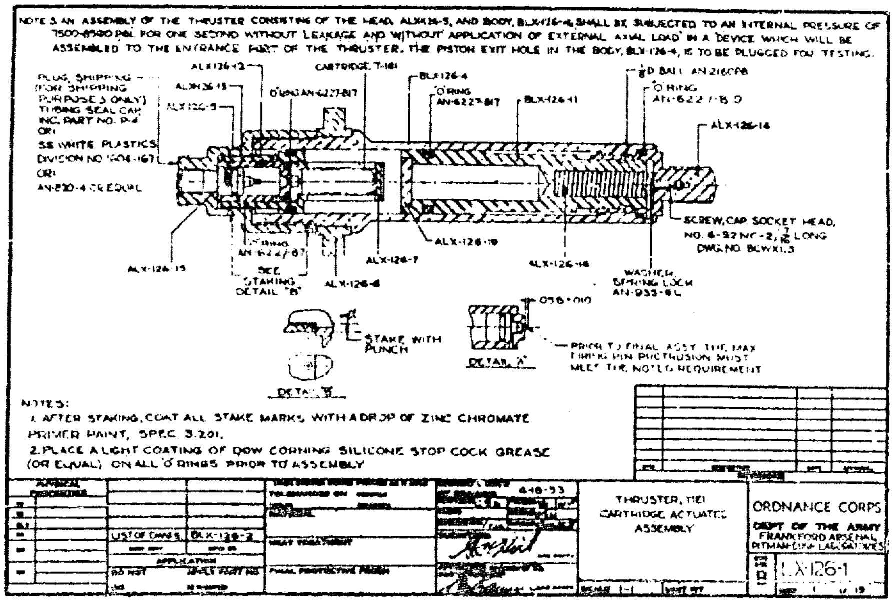
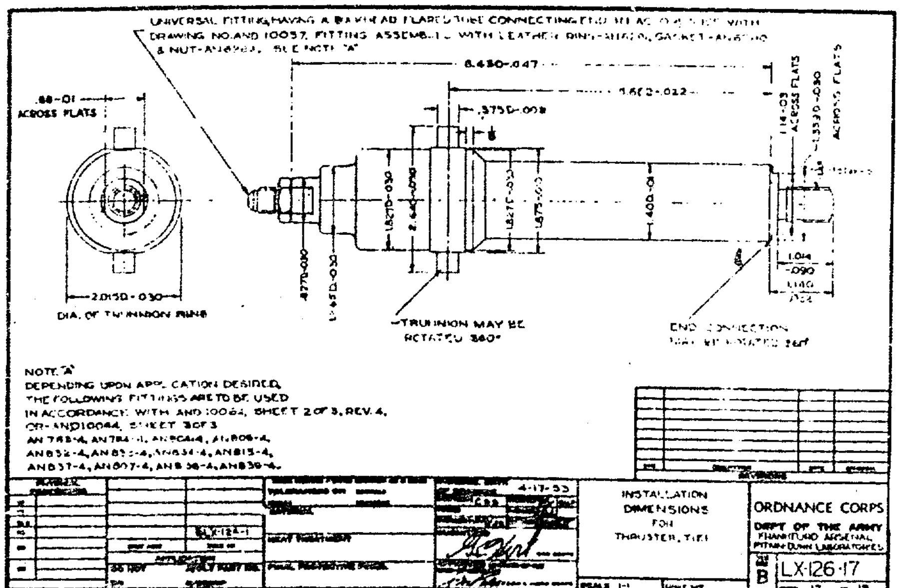


Figure 6. Tail cone jettiscning system for B-52 Airplane

Neg. #24498 7
R-1183



A



B

Figure 7. Thruster, T1E1
A - Assembly
B - Installation dimensions

Neg. #24498-8
R-1183

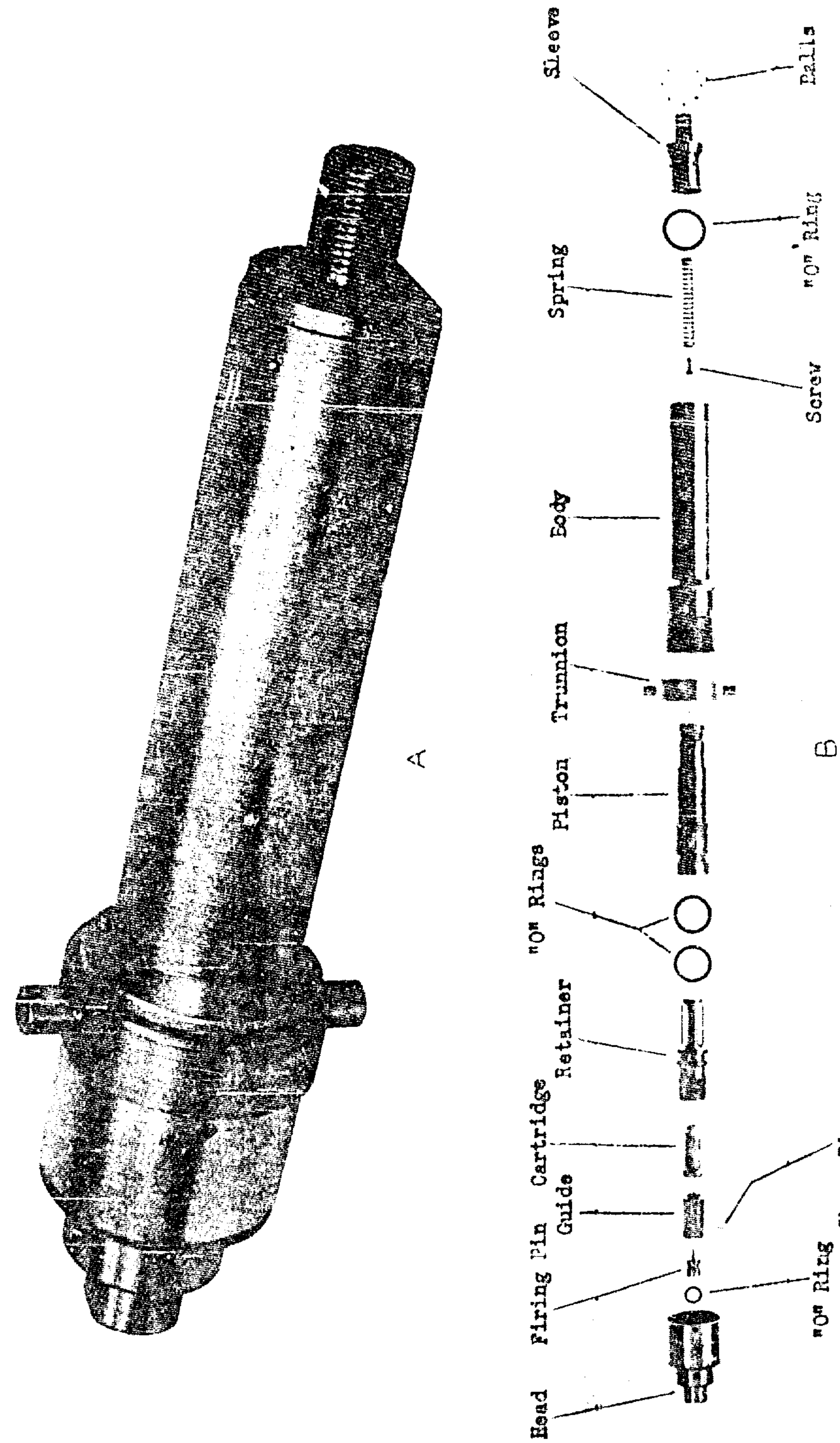


Figure 8. Thruster, T1E1
A - Assembled
B - Exploded view

Neg. #24498-9
R-1183

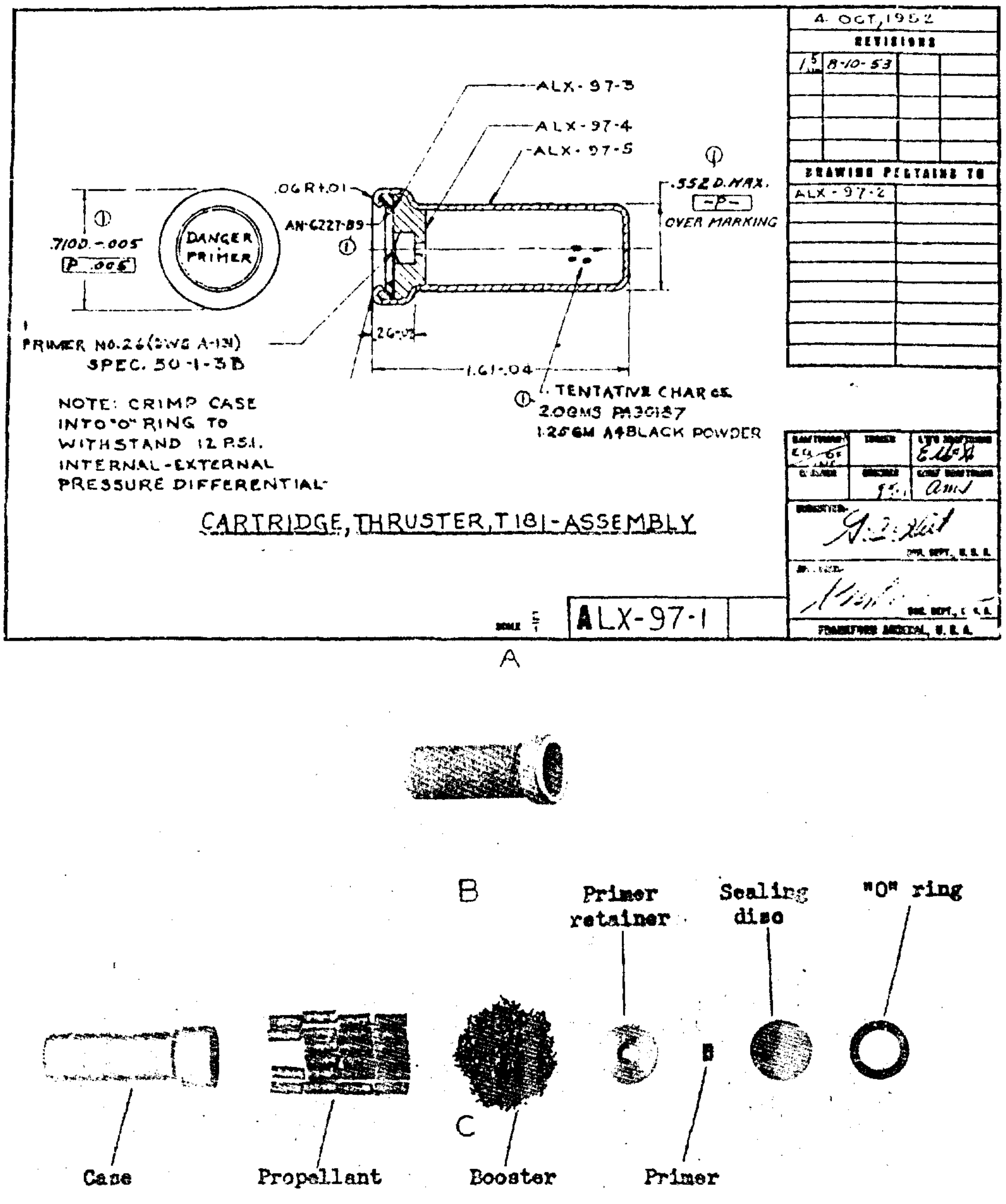


Figure 9. Cartridge, T181
A - Assembly
B - Assembled
C - Exploded view

Neg. #24498-10
R-1183

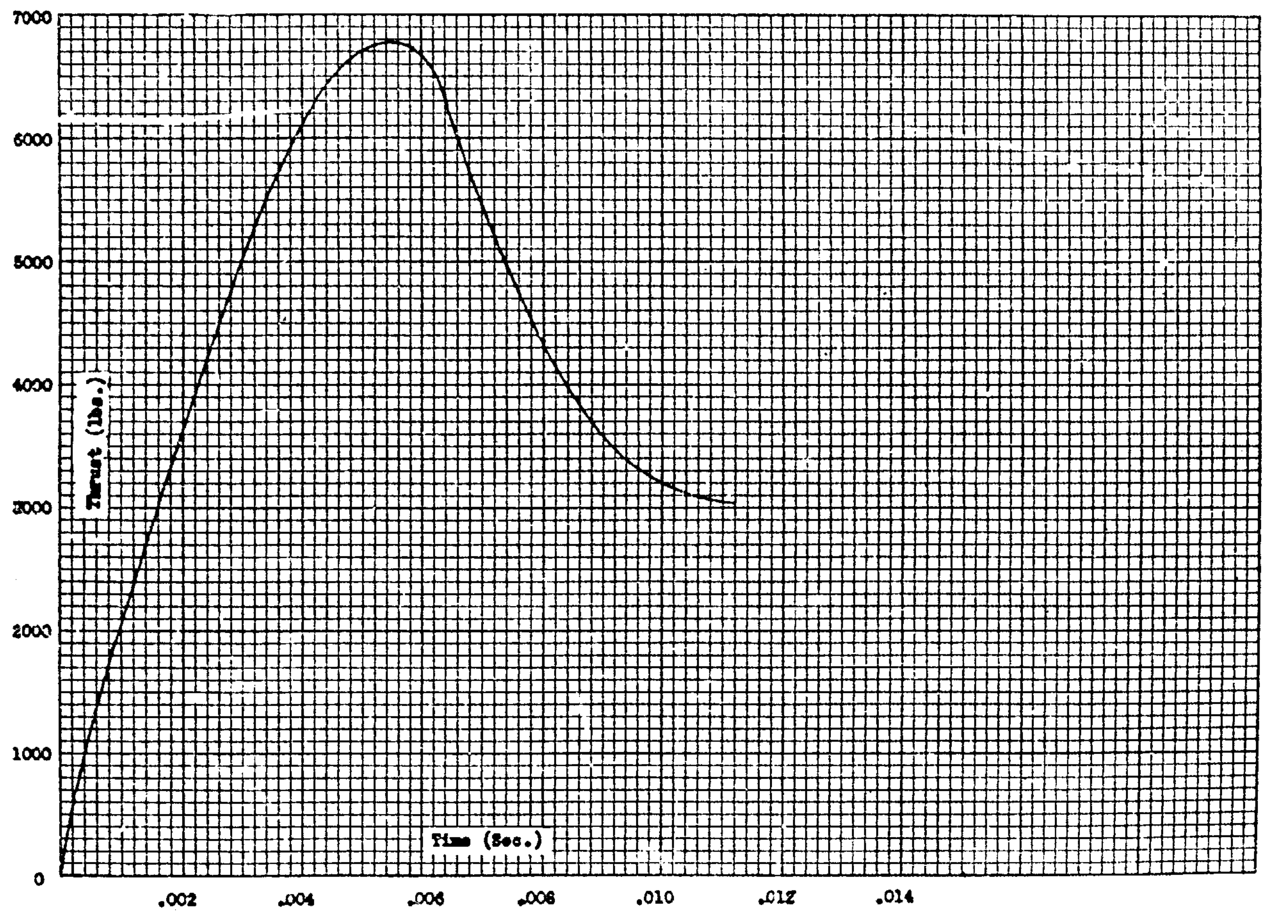
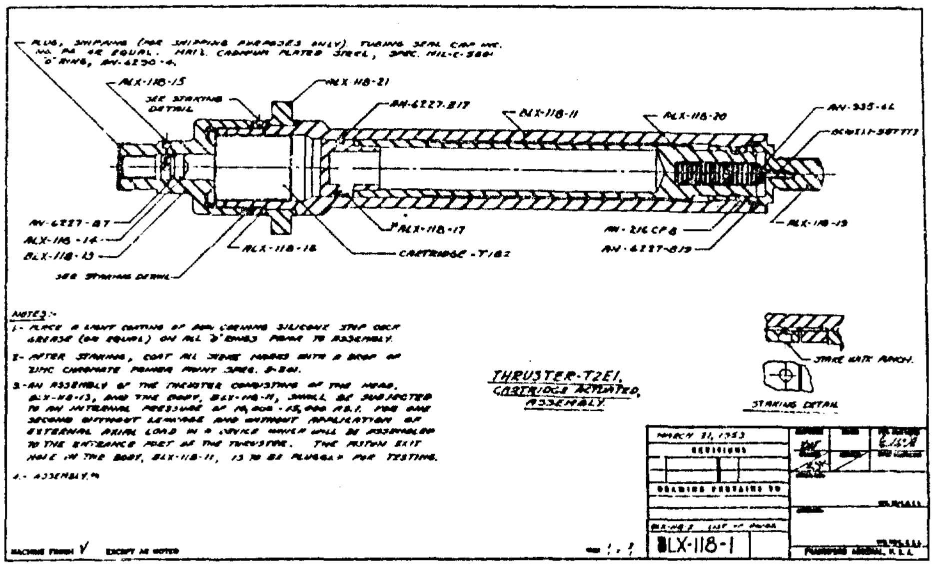
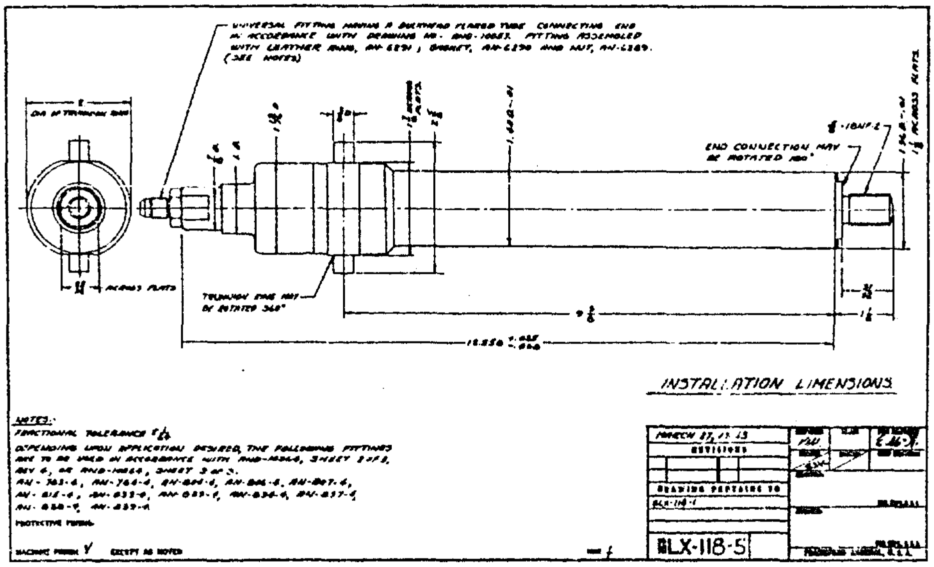


Figure 10. Thrust-Time curve for Cartridge, T181 (2.0 gm PA 30187 and 1.25 gm A4 BP) in Thruster, T1E1 (20 lb propelled mass, shear pins requiring 1000 lb at 0-in. stroke, 6000 lb at 0.25 inch, 3200 lb at 0.40 inch, and 1000 lb at 0.75 inch)

Neg. #24498-11
R-1183



A



B

Figure 11. Thruster, T2E1
A - Assembly
B - Installation dimensions

Neg. #24498-12
R-1183

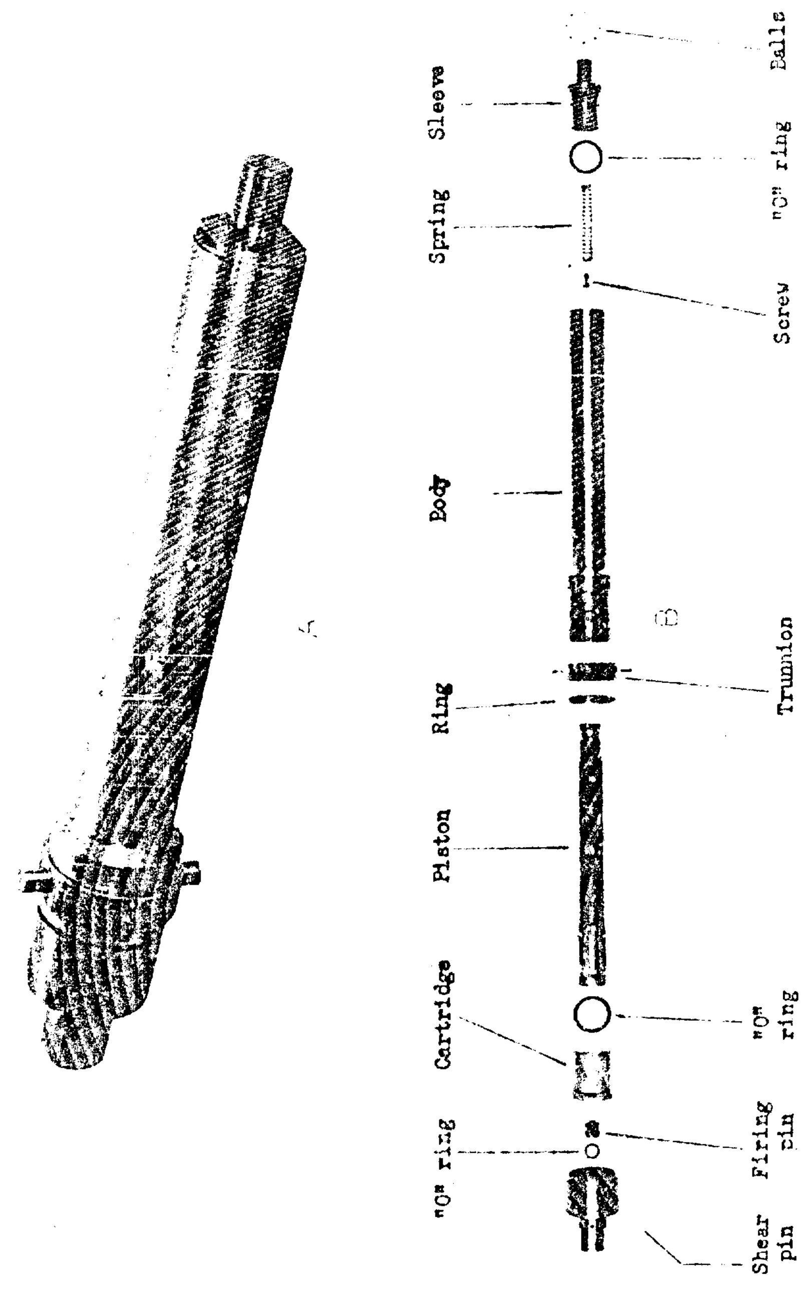


Figure 12. Thruster, T2E1
A - Assembled
B - Exploded view

Neg. #24498-13
R-1183

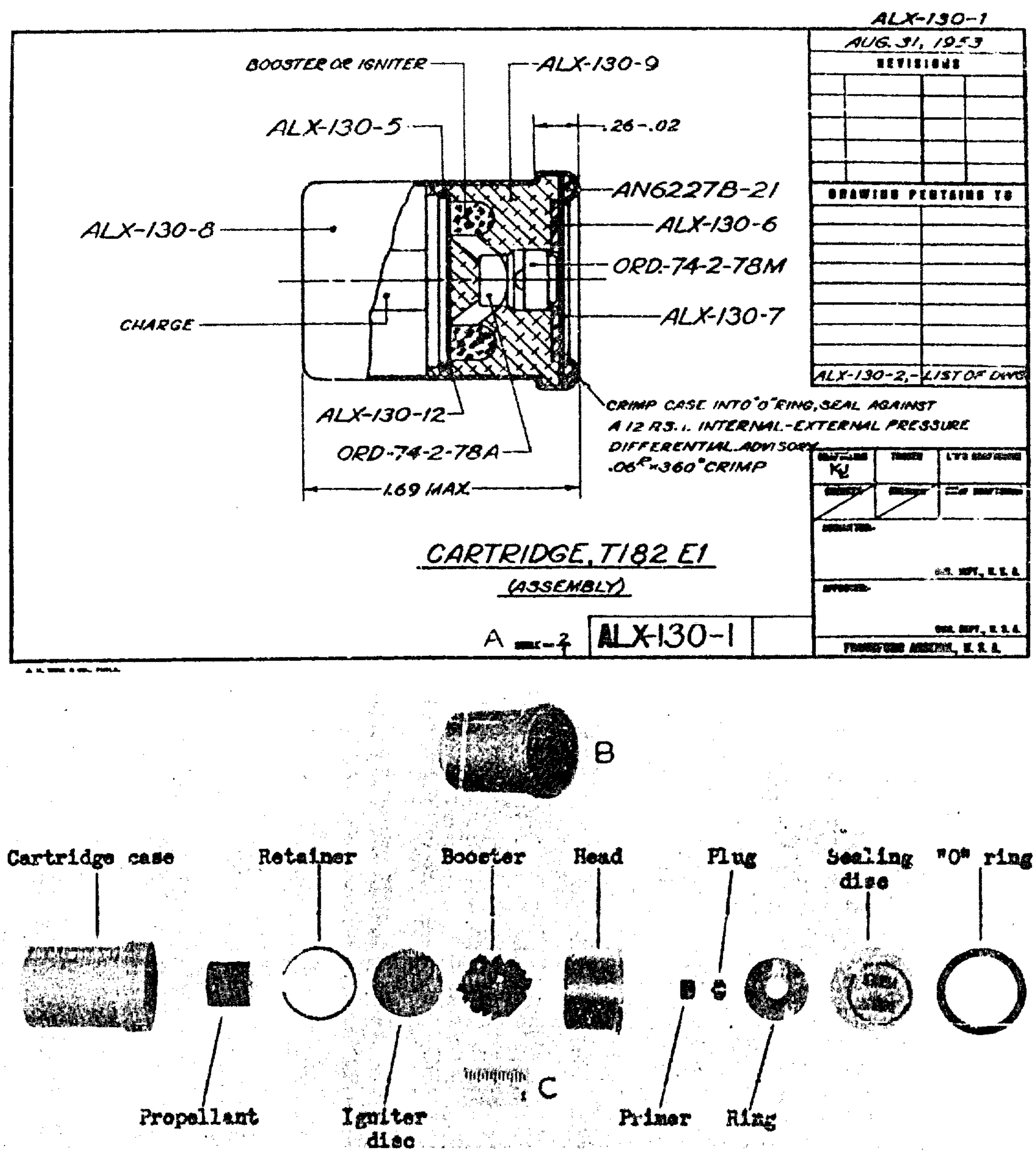


Figure 13. Cartridge, T182E1
A - Assembly
B - Assembled
C - Exploded view

Neg. #24498-14
R-1183

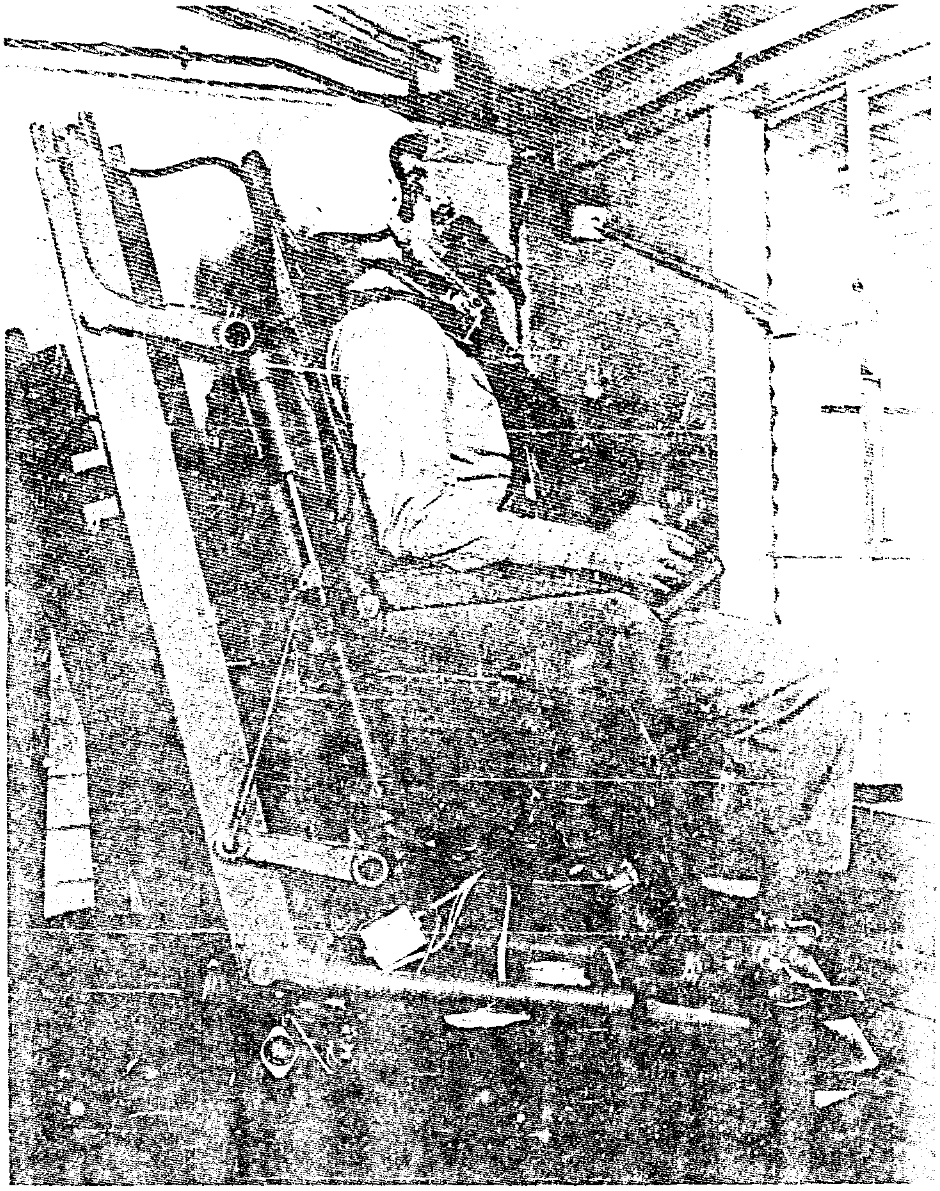


Figure 14. Upward seat ejection system - Weber seat

Neg. #44498-15
R-1183

Pneumatic cylinder used in place of Thruster, Cartridge Actuated, T2E2, for mechanical tests.

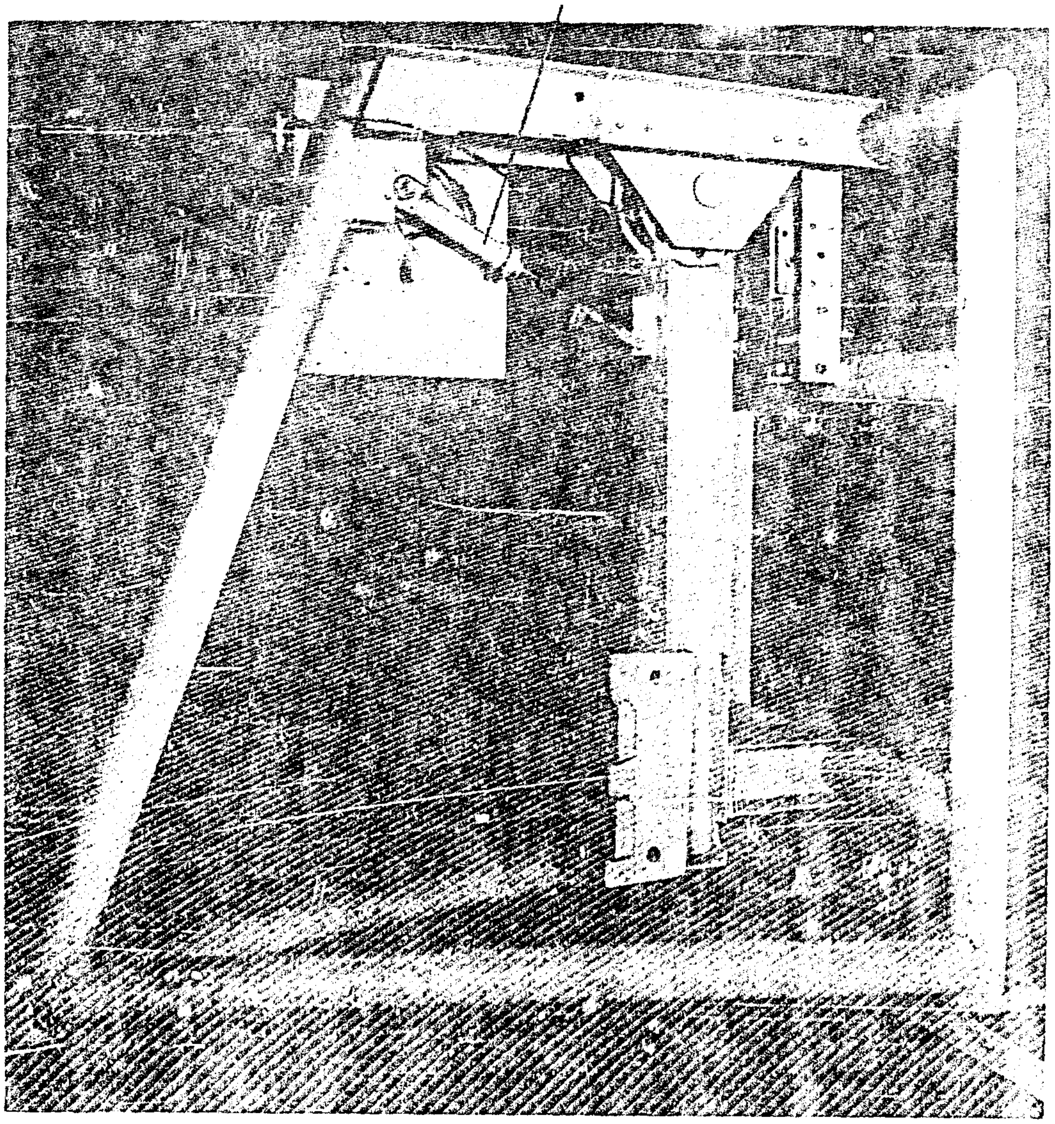
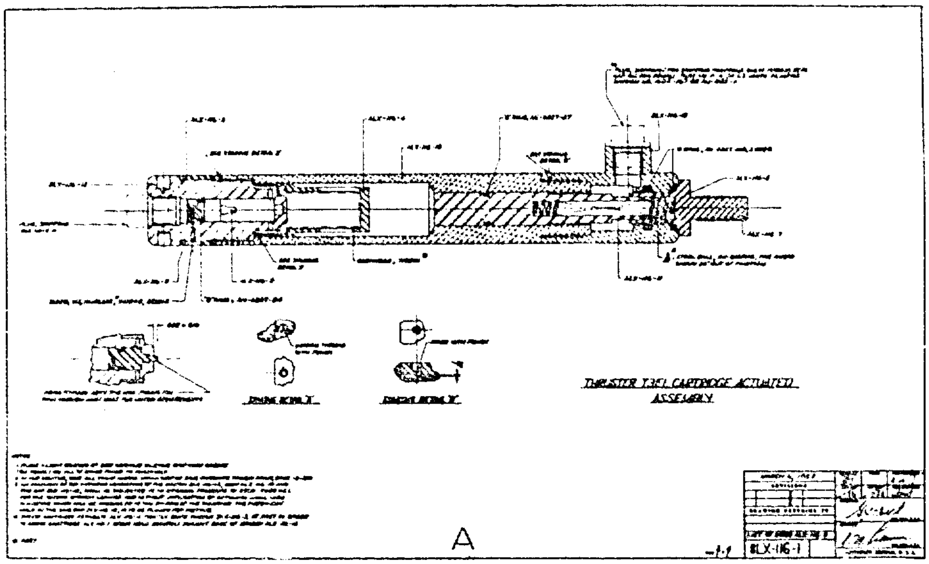
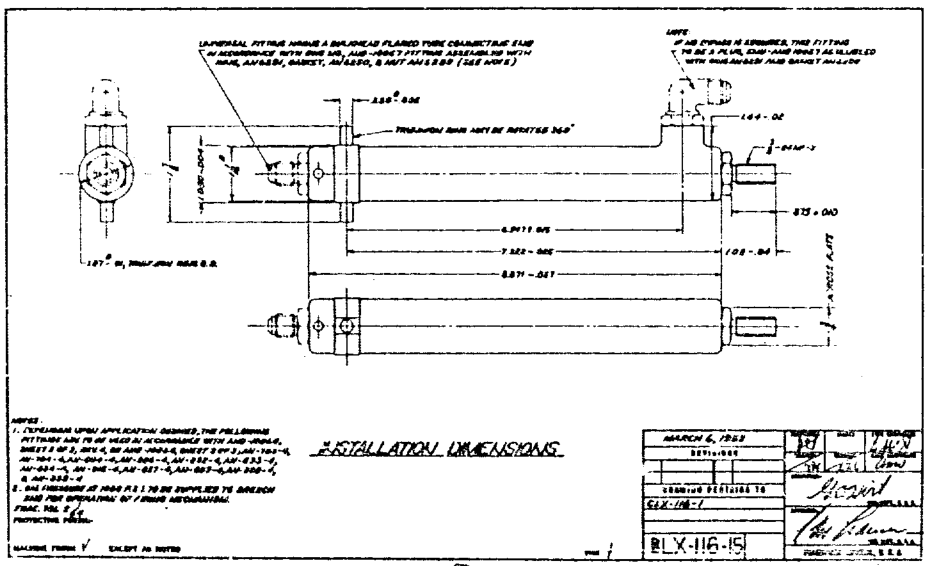


Figure 15. Downward seat ejection system - Boeing mockup

Neg. #24498-16
R-1183

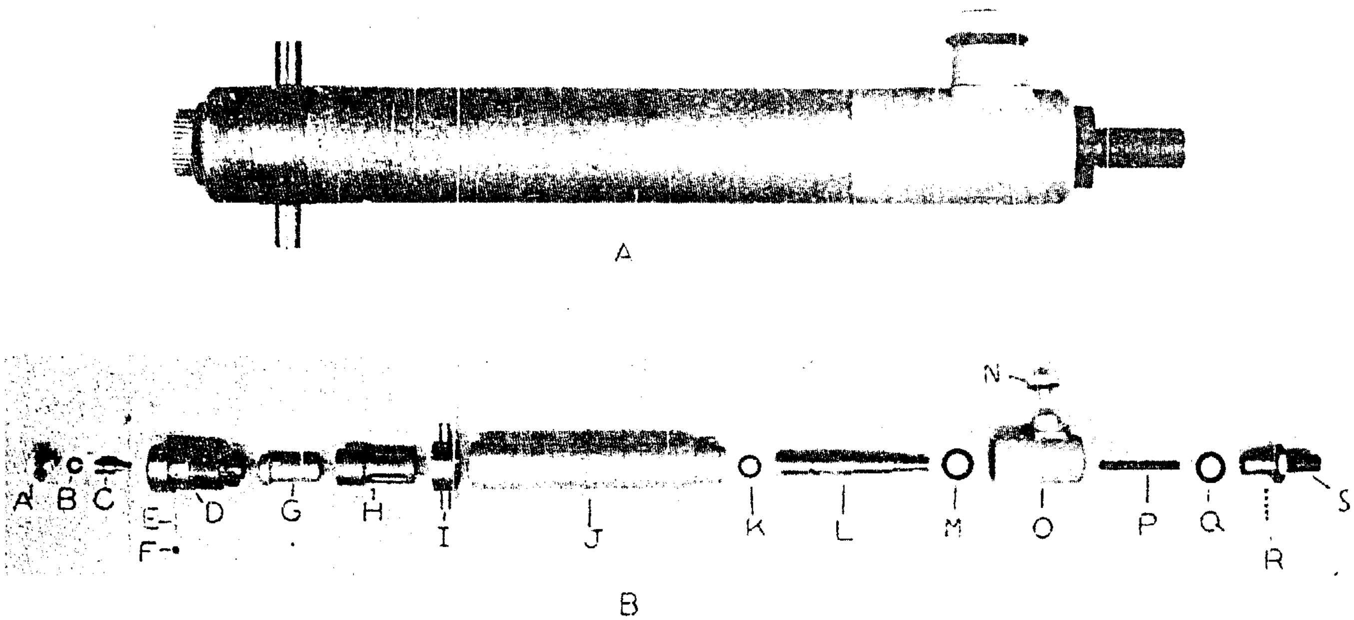




B

Figure 16. Thruster, T3E1
A - Assembly
B - Installation drawing

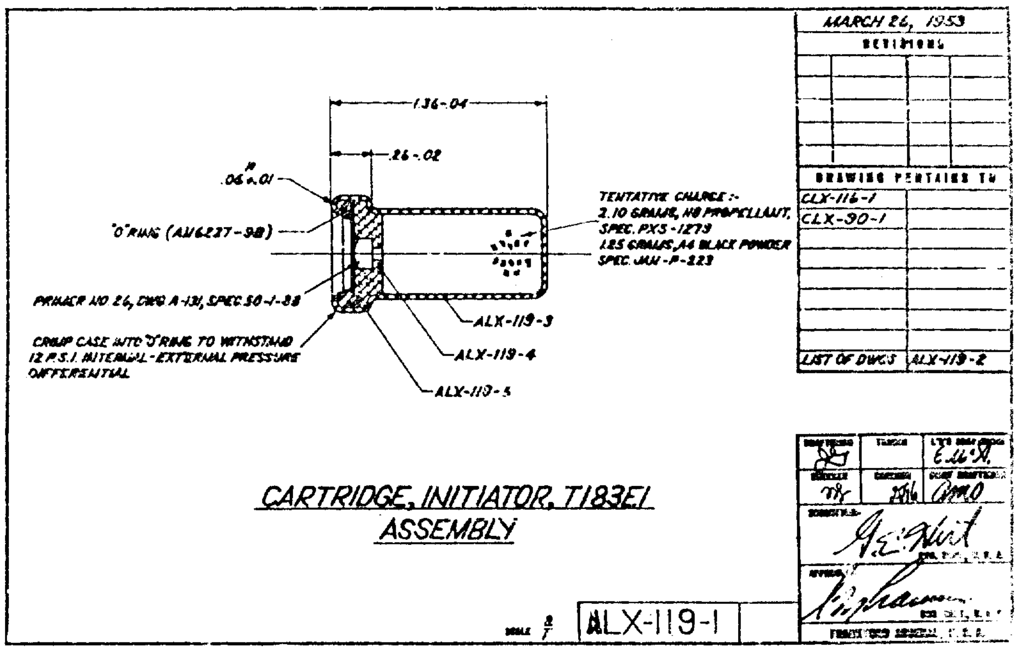
Neg. #24498-17
R-1183



A - Dust cap	F - Set screw	K - "0" ring	P - Piston locking spring
B - "0" ring	G - Cartridge	L - Piston	Q - "O" ring
C - Firing pin	H - Cartridge holder	M - "0" ring	R - Locking balls
D - Breech	I - Trunnion mounting	N - Dust cap	S - Connecting sleeve
E - Shear pin	J - Body	O - End cap	

Figure 17. Thruster, T3E1
A - Assembled
B - Exploded view

Neg #24498-18
R-1183



A

Cartridge case | Propellant | Booster | Primer retainer | Primer | Sealing disc | "O" ring

B

C

Figure 18. Cartridge, T183E1
A - Assembly
B - Exploded view
C - Assembled

Neg #24498-19
R-1183

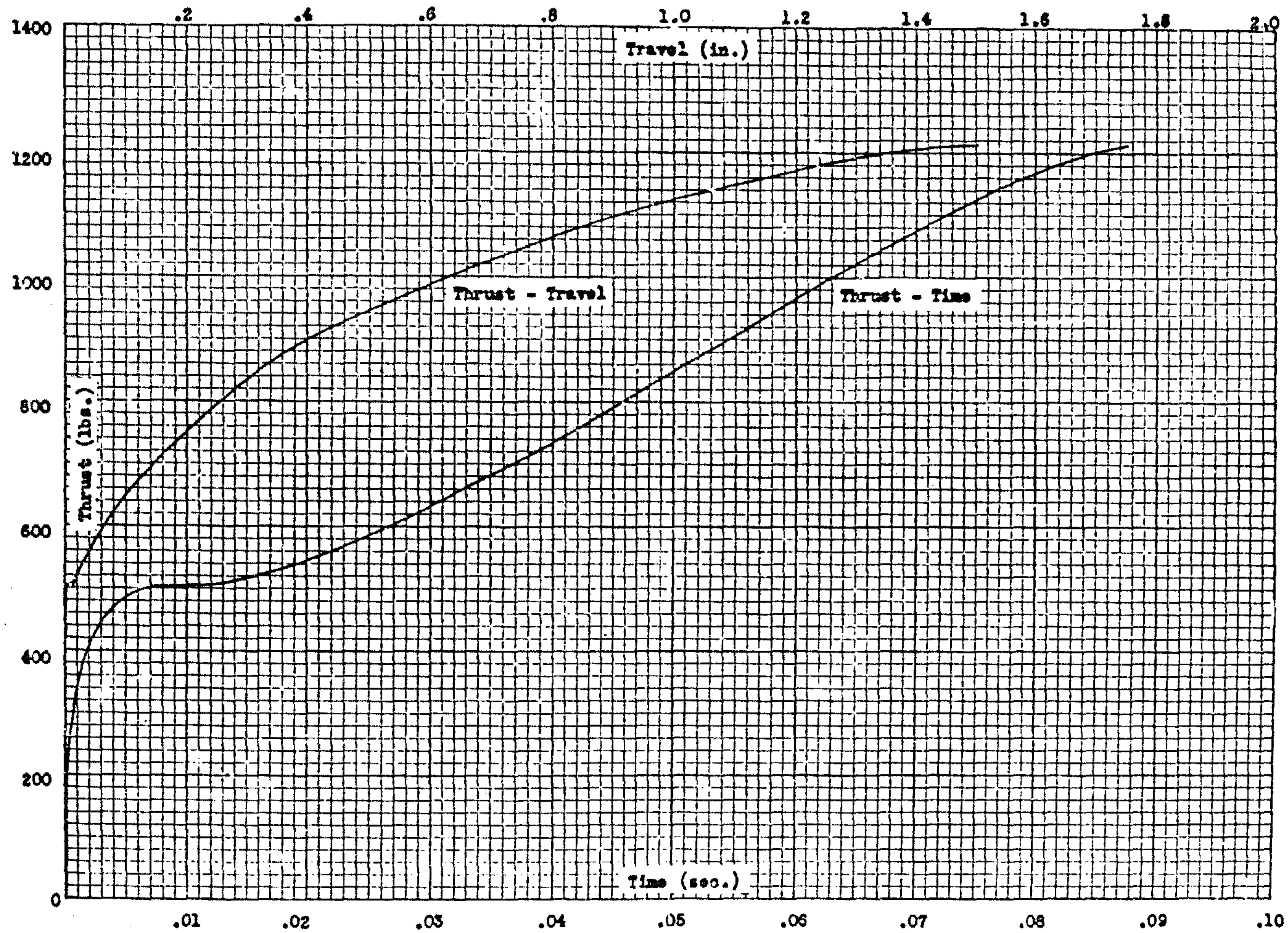
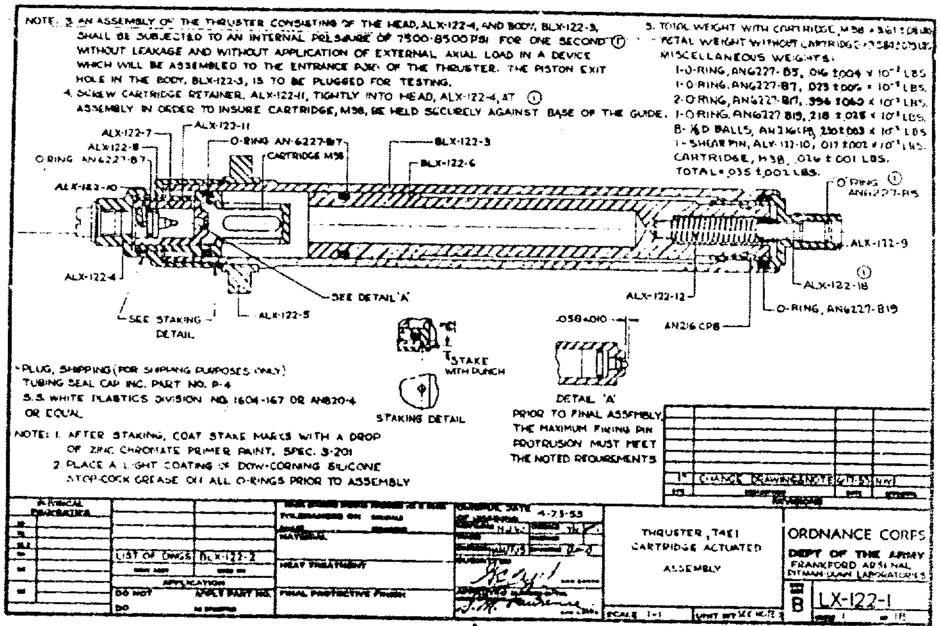
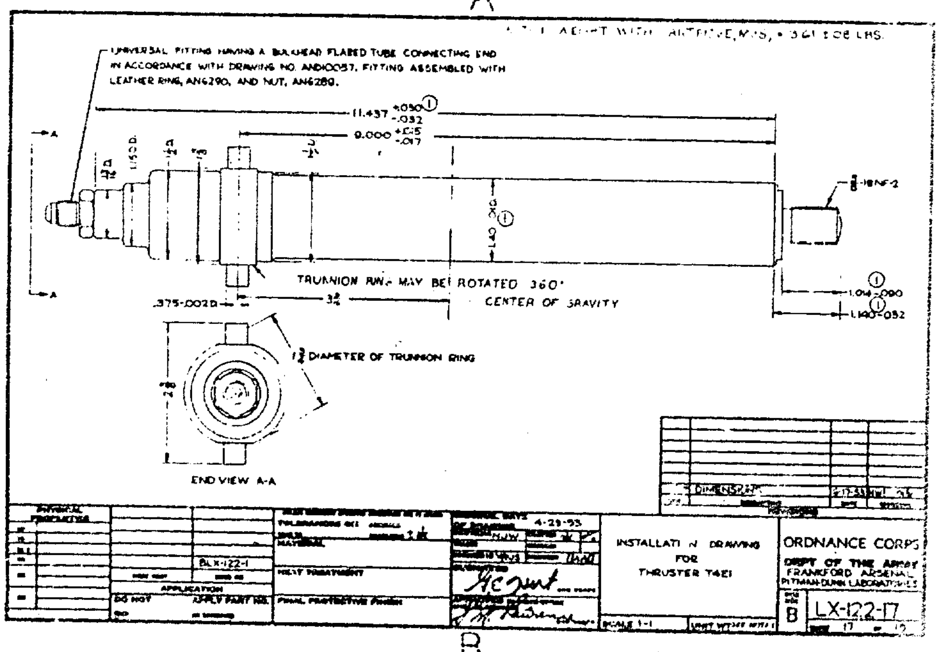


Figure 19. Thrust-Time and Thrust-Travel relationships obtained in propelling a 323 lb mass vertically with Thruster, T3E1, and Cartridge, T183E1 (2.1 gm 5130.12 and 1.25 gm A4 BP)

Neg. #24498-20
R-1183



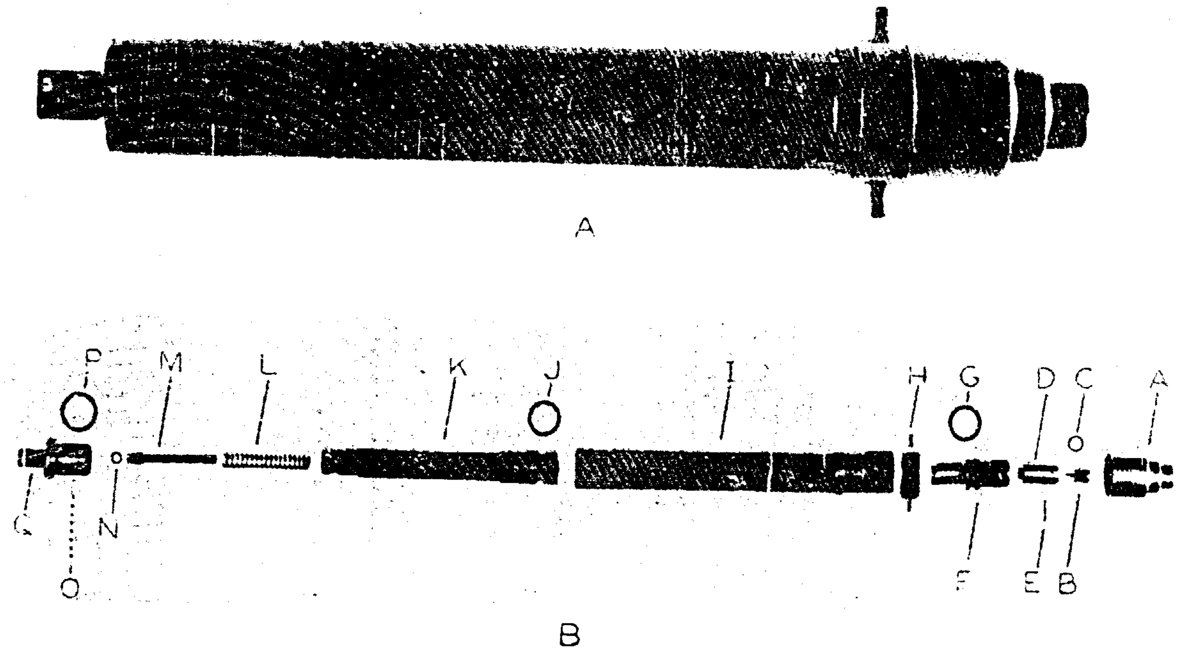
A



B

Figure 20. Thruster (M5), T4E1
A - Assembly
B - Installation drawing

Neg. #2-498-21
R-1183



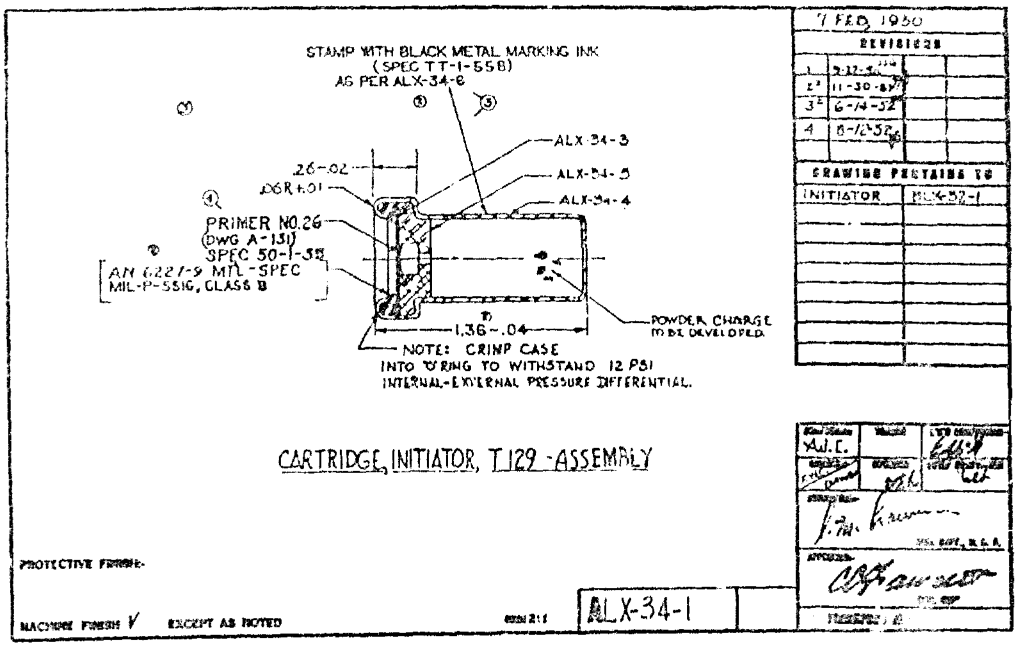
A - Head
B - Firing pin
C - "0" ring
D - Firing pin guide
E - Shear pin
F - Cartridge retainer

G - "0" ring
H - Trunnion mount
I - Body
J - "0" ring
K - Piston rod
L - Piston locking spring

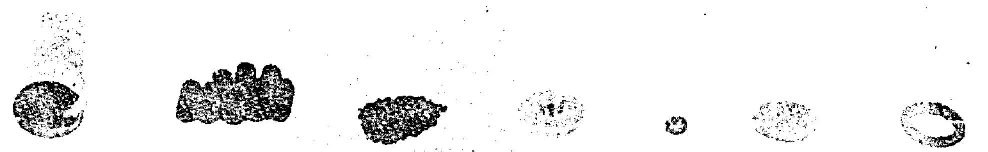
M - Buffer screw
N - "0" ring
O - Locking bails
P - "0" ring
Q - End sleeve

Figure 21. Thruster (M5), T4E1
A - Assembled
B - Exploded view

Neg. #24498-22
R-1183

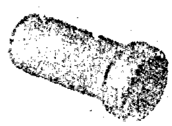


A



Cartridge case | Propellant | Booster | Primer retainer | Primer | Sealing disc | "O" ring

B



C

Figure 22. Cartridge, M38 (T129)
A - Assembly
B - Exploded view of cartridge
C - Assembled cartridge

Neg. #24498-23
R-1183

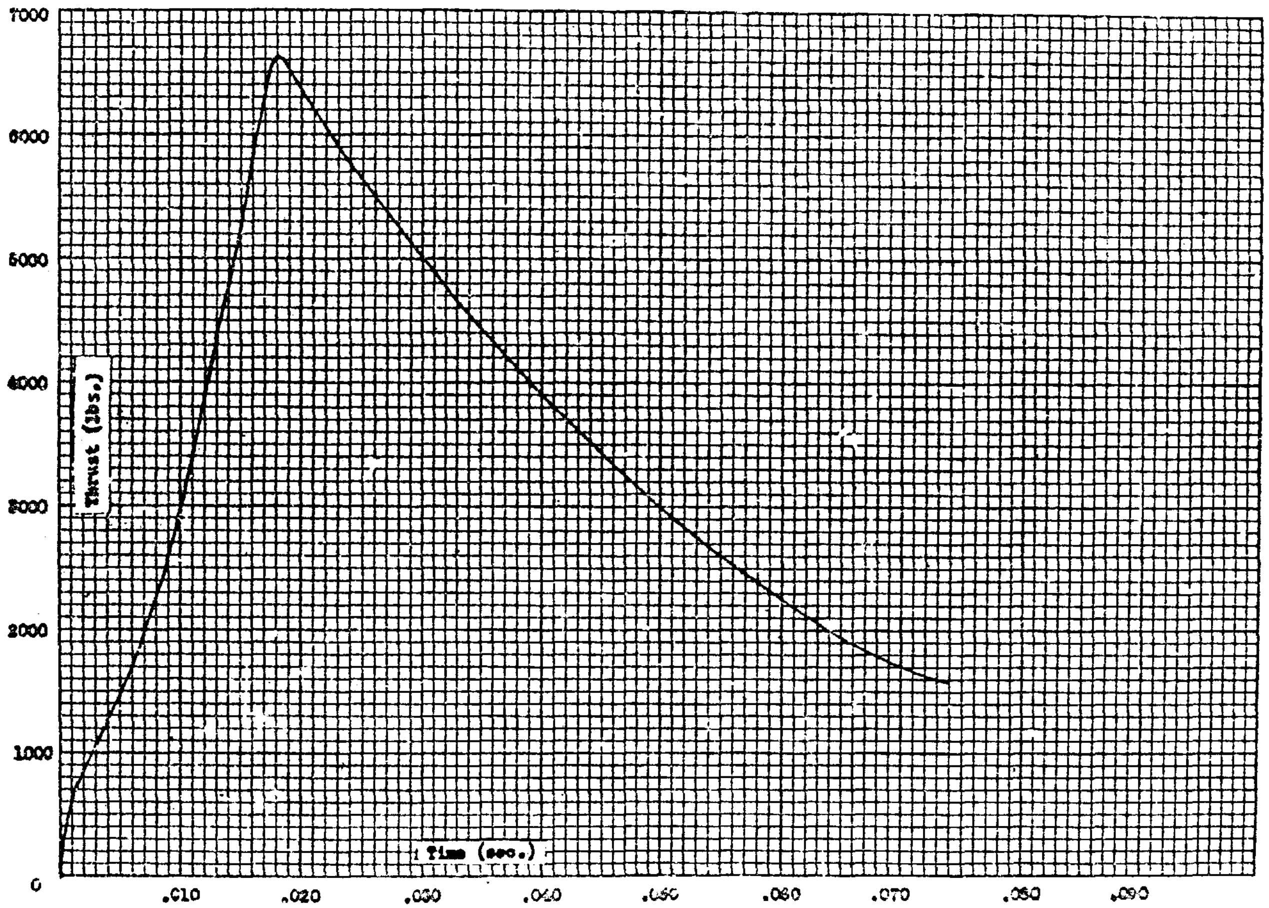
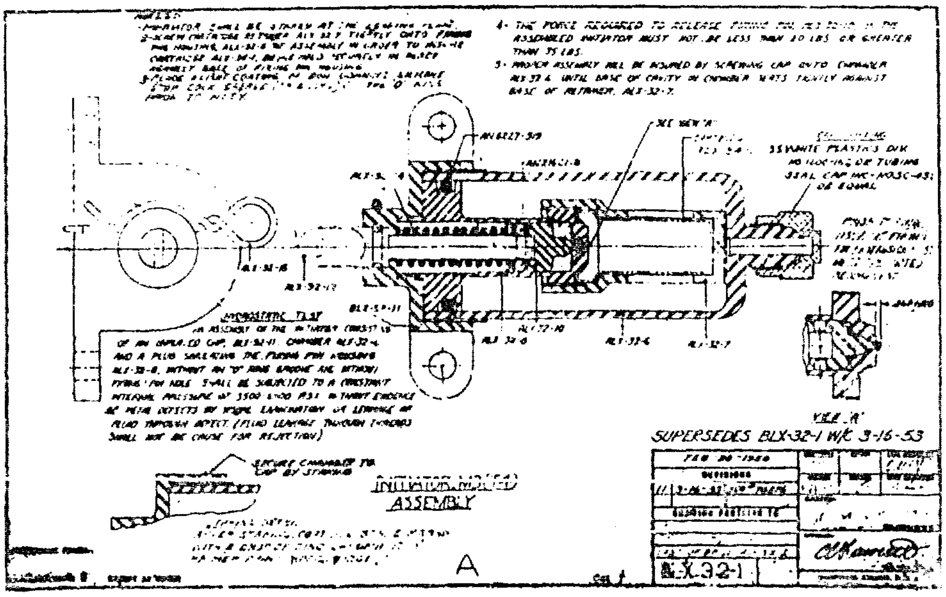


Figure 23. Thrust-Time relationship obtained with Cartridge, M38, in Thruster, T4E1 (500 lb propelled mass, 4000 lb shear pin at 0-in. stroke, and a 1000 lb shear pin at 5-in. stroke)

Neg. #24498-24
R-1183



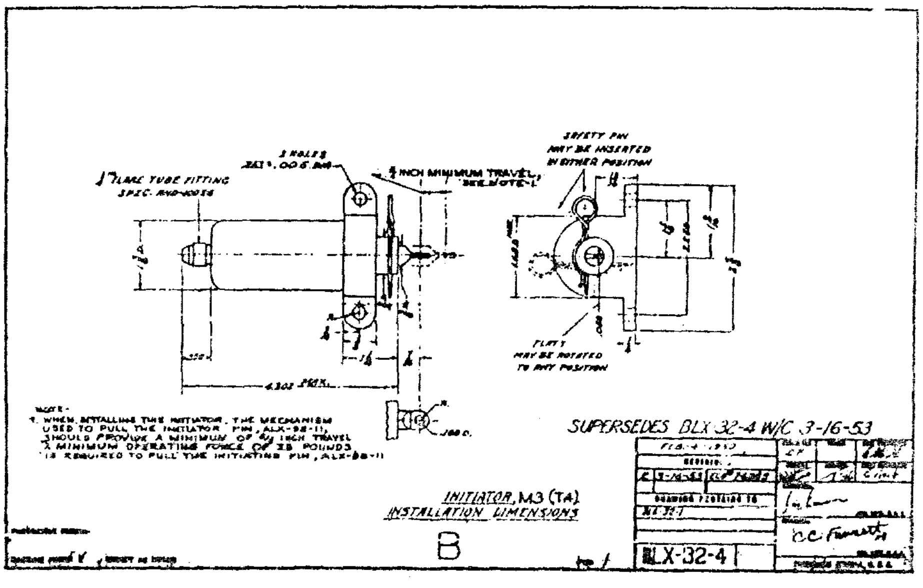


Figure 24. Initiator, M3 (T4)
A - Assembly
B - Installation dimensions

Neg. #24498-25
R-1183

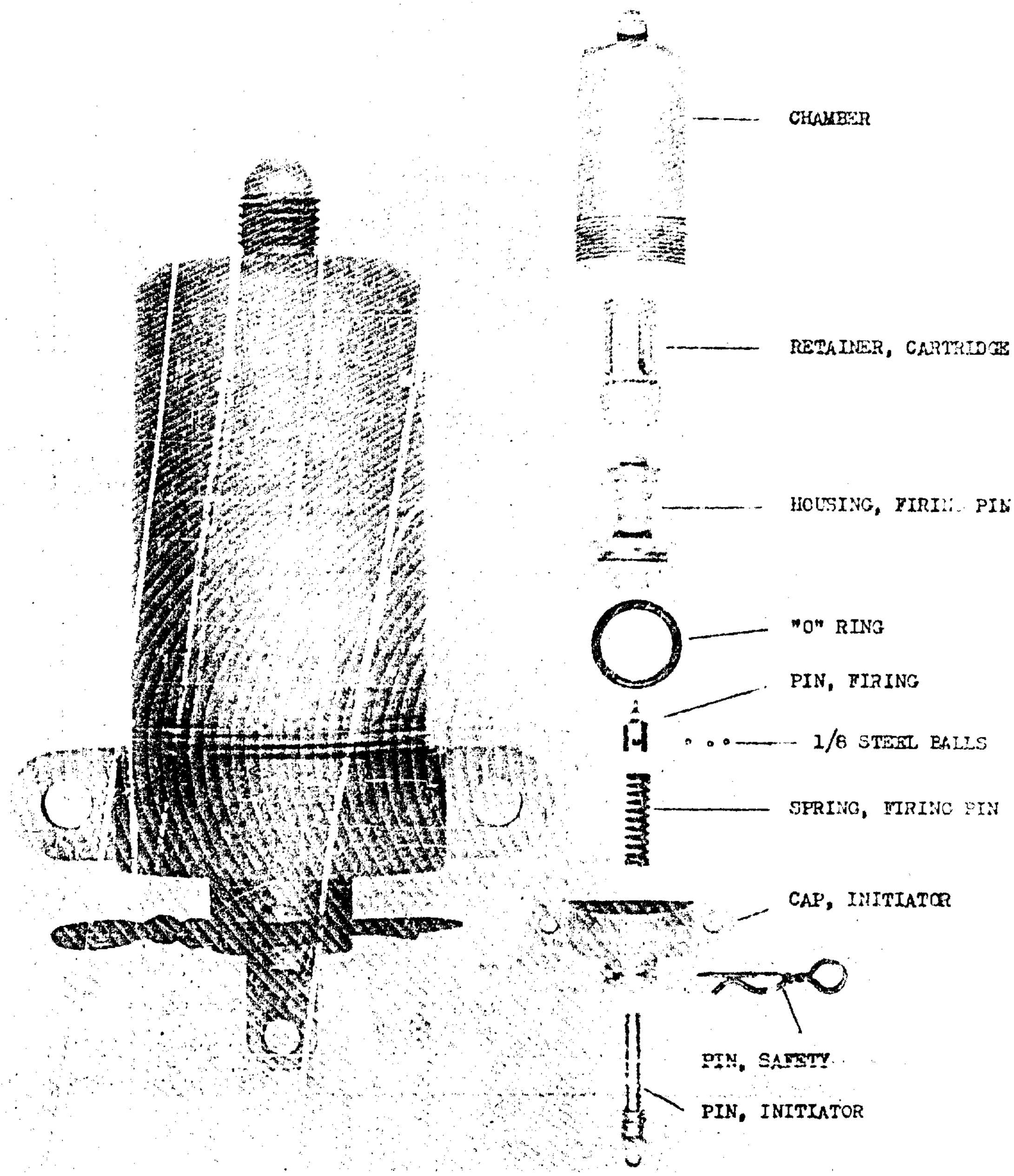
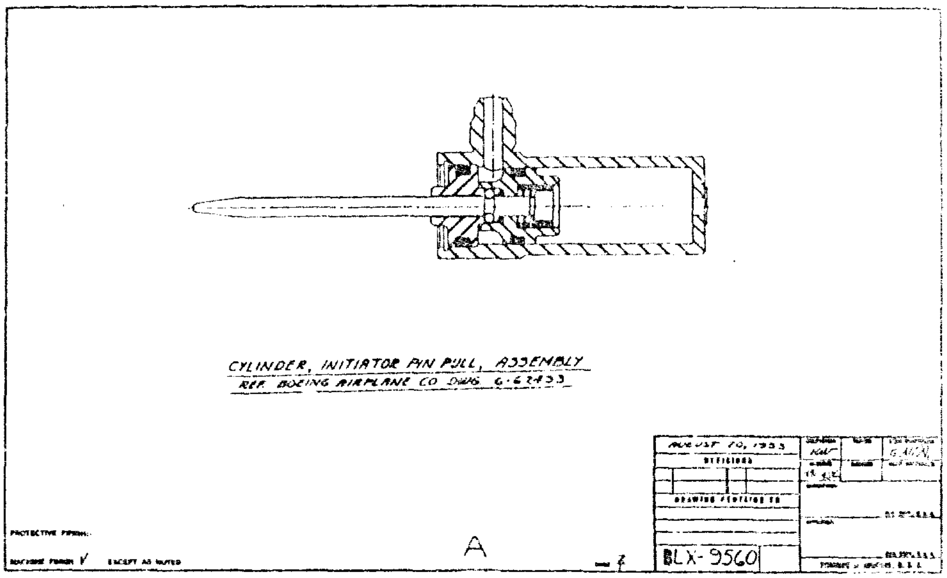


Figure 25. Initiator, M3 (T4)
A - Assembled
B - Exploded view

Neg. #24498-26
R-1183



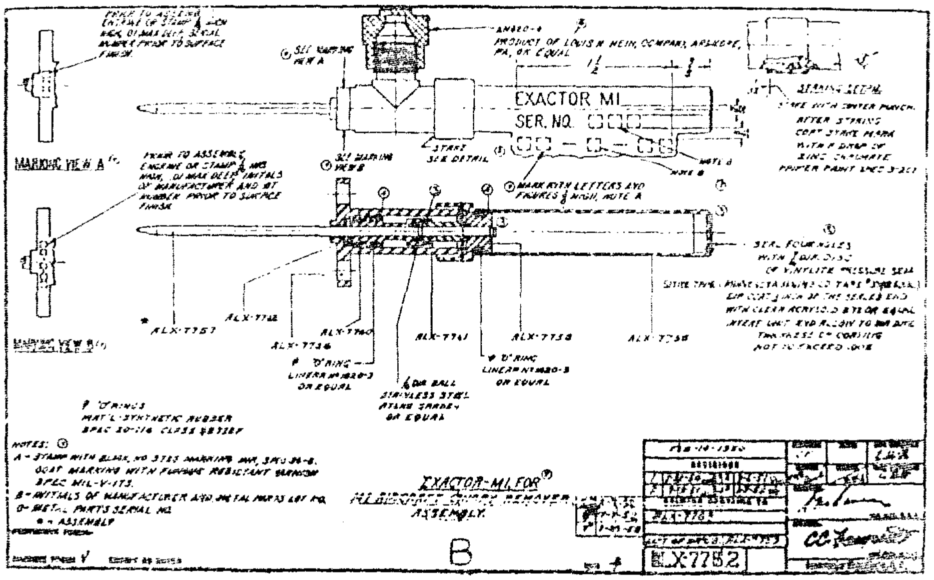


Figure 25. A - Boeing Exactor - Assembly
B - Exactor, M1 (T1) - Assembly

Neg. #24498-27
R-1183

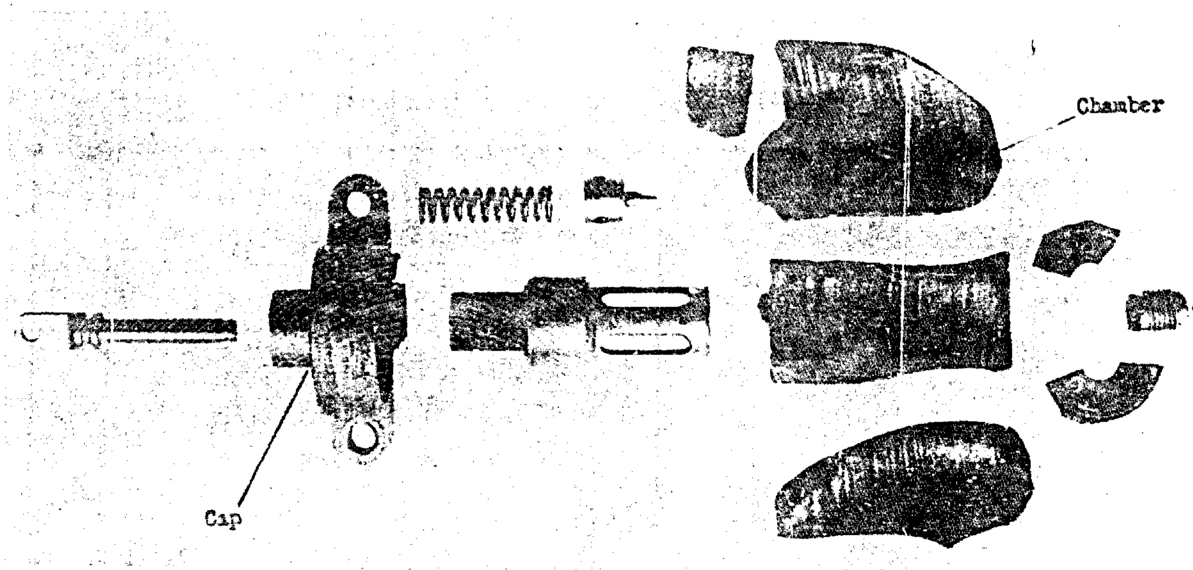
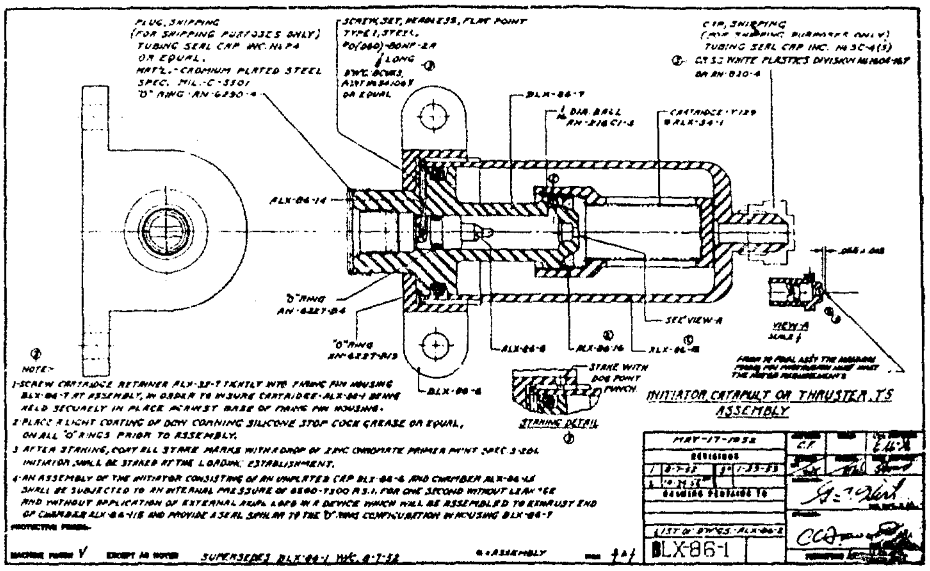
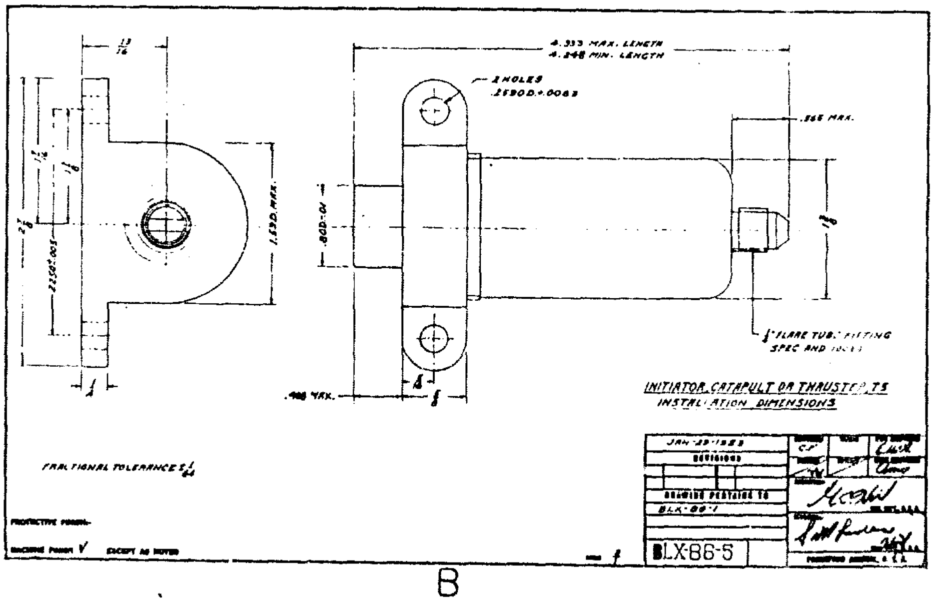


Figure 27. Initiator, M3 (T4) - malfunction
Cap - WD 4140, Rc 6
Chamber - WD 4140, Rc 16 to 18

Neg. #24498-28
R-1183



A



B

Figure 28. Initiator, M5 (T5)
A - Assembly
B - Installation dimensions

Neg. #24498-29
R-1183

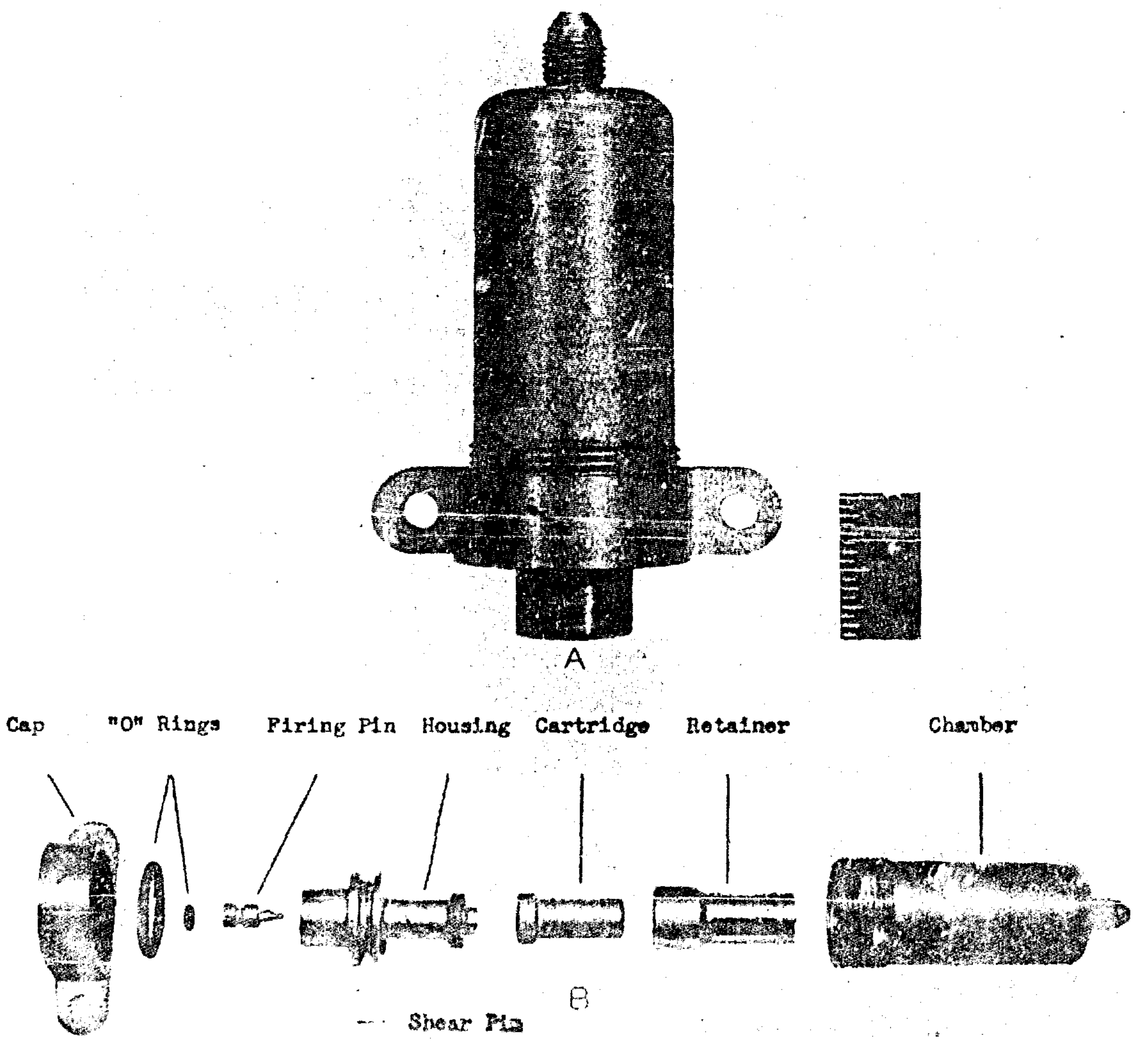
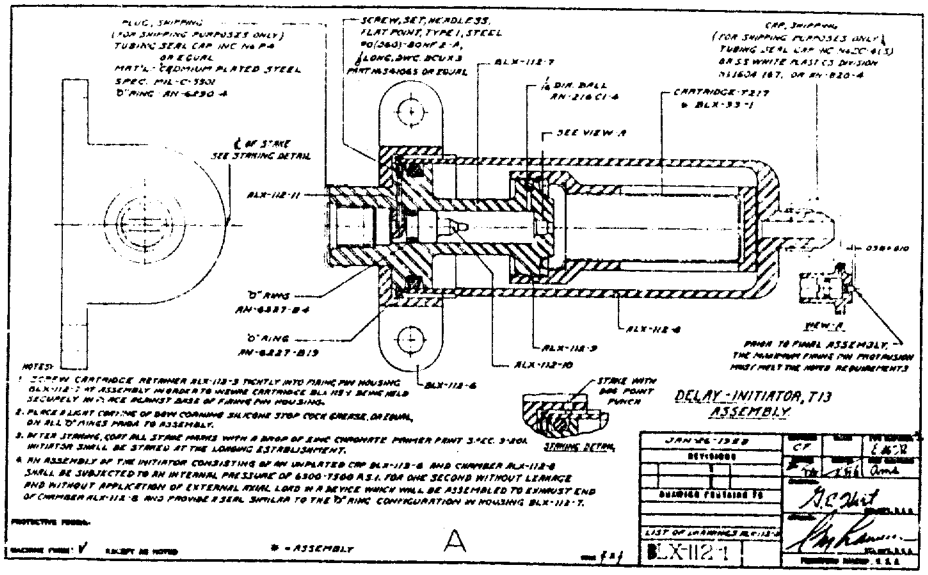
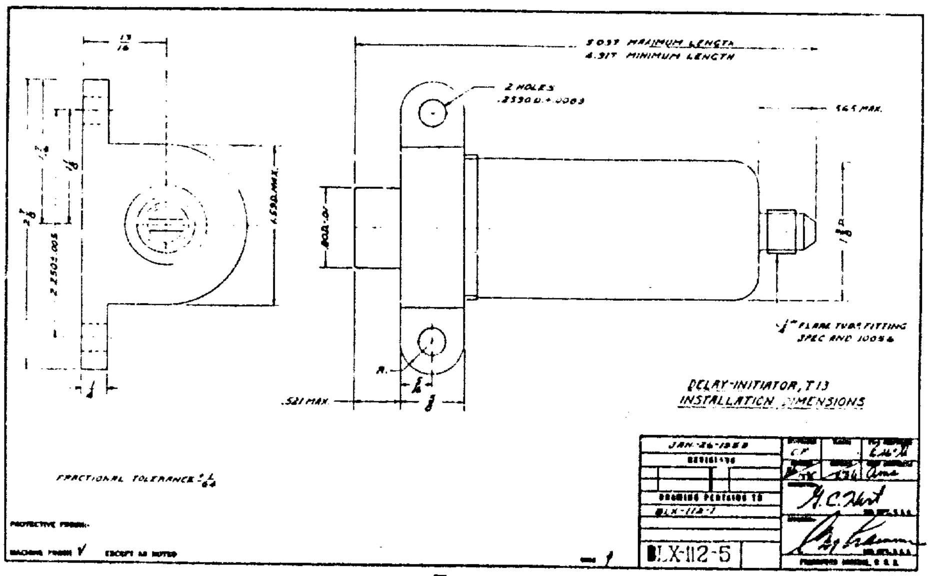


Figure 29. Initiator, M5 (T5)
A - Assembled
B - Exploded view

Neg. #24498-30
R-1183





B

Figure 30. Initiator, M6 (T13)
A - Assembled
B - Installation dimensions

Neg. #24498-31
R-1183

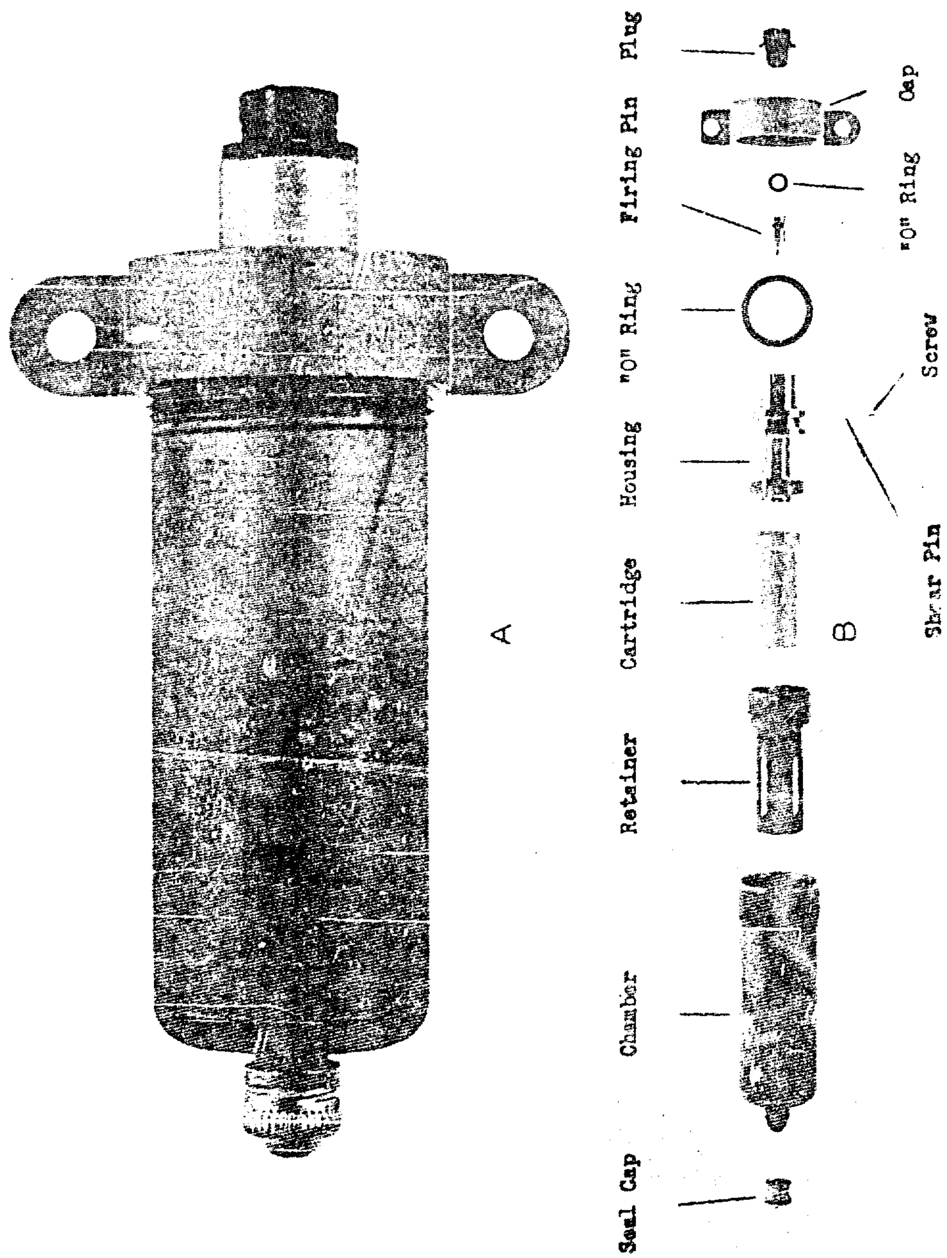
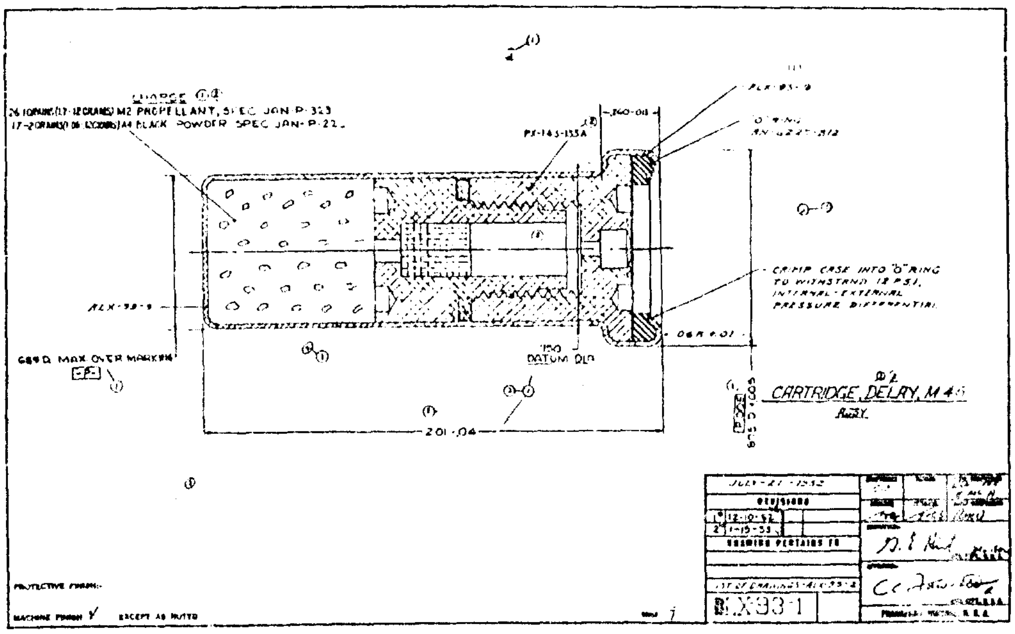
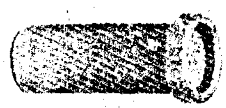


Figure 31. Delay-Initiator, M6 (T13)
A - Assembled
B - Exploded view

Neg. #24498-32
R-1183



A



B

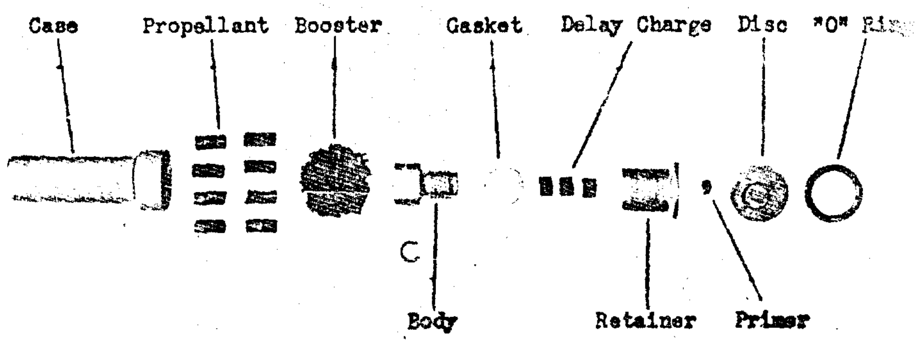


Figure 32. Cartridge, T217
A - Assembly
B - Assembled
C - Exploded view

Neg. #24498-33
R-1183

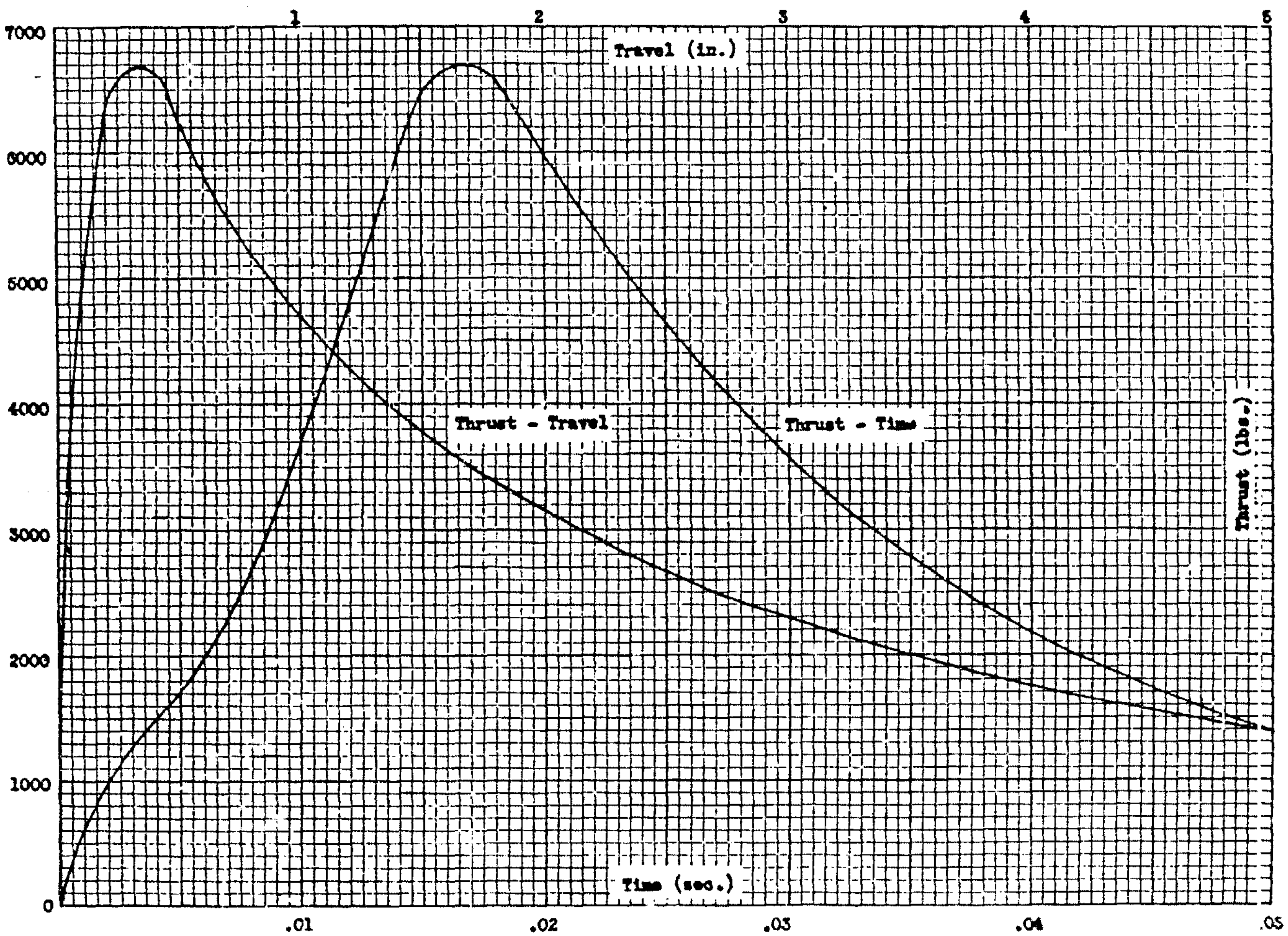


Figure 33. Thrust-Time and Trust-Travel relationships obtained in propelling a 323-lb mass vertically with Thruster, T4, and Cartridge, M38

Neg. #24498-34
R-1183

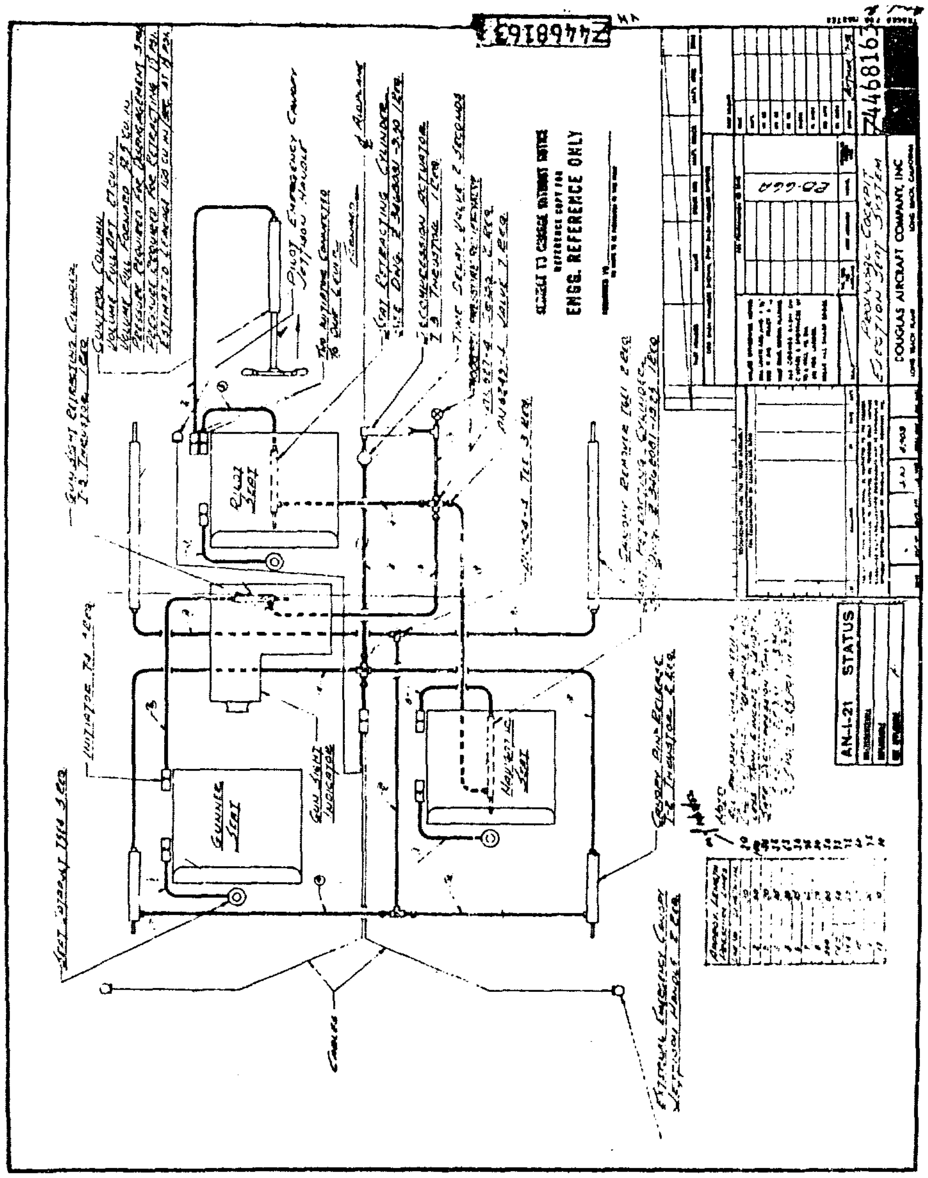


Figure 34. Ejection system first proposed by Douglas Aircraft Co., Inc. for RB-66 and B-66 Airplanes

Neg. #24498-35
R-1183

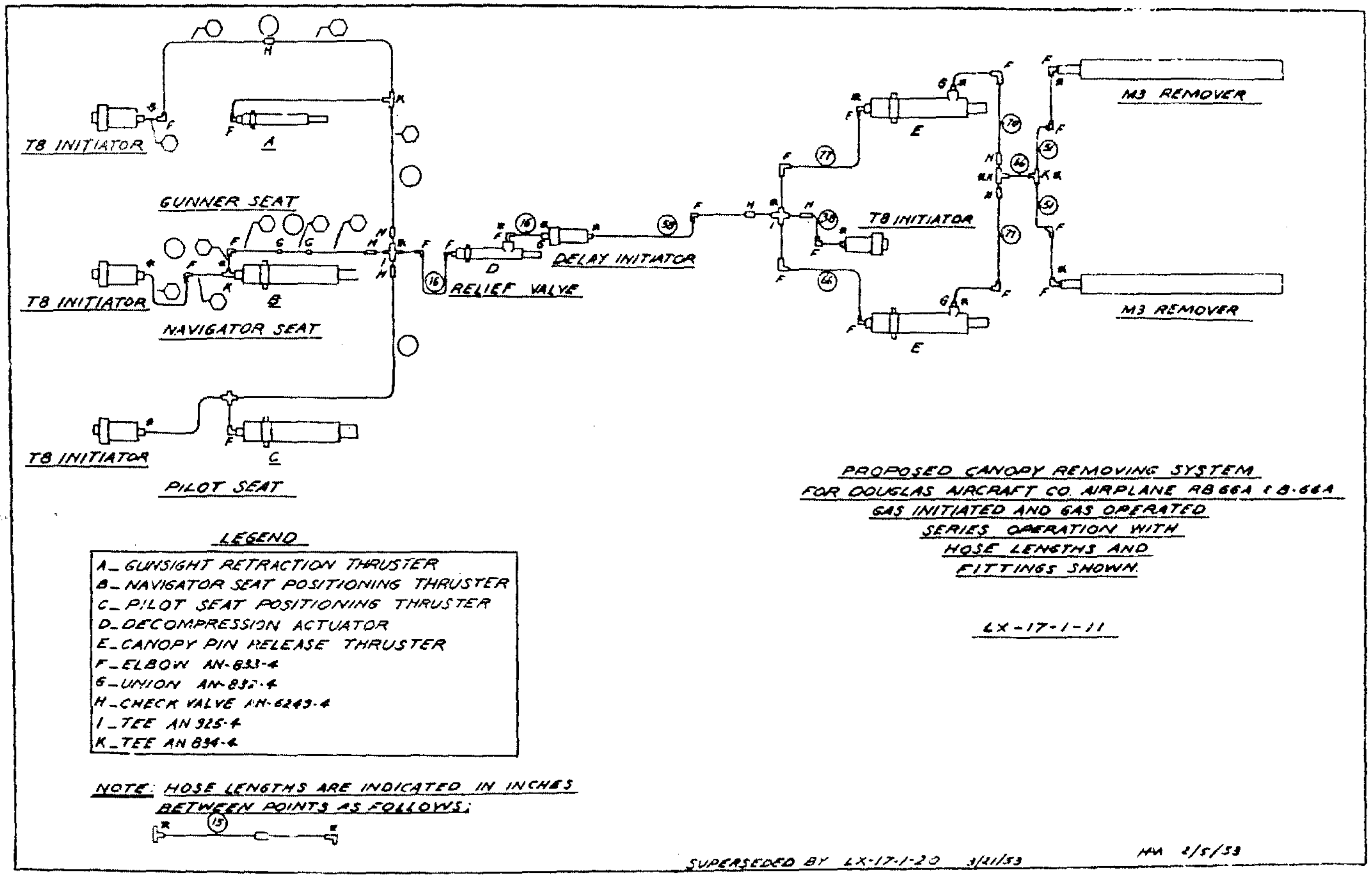


Figure 35. Revised ejection system first proposed by Frankford Arsenal

Neg. #24498-36
R-1183

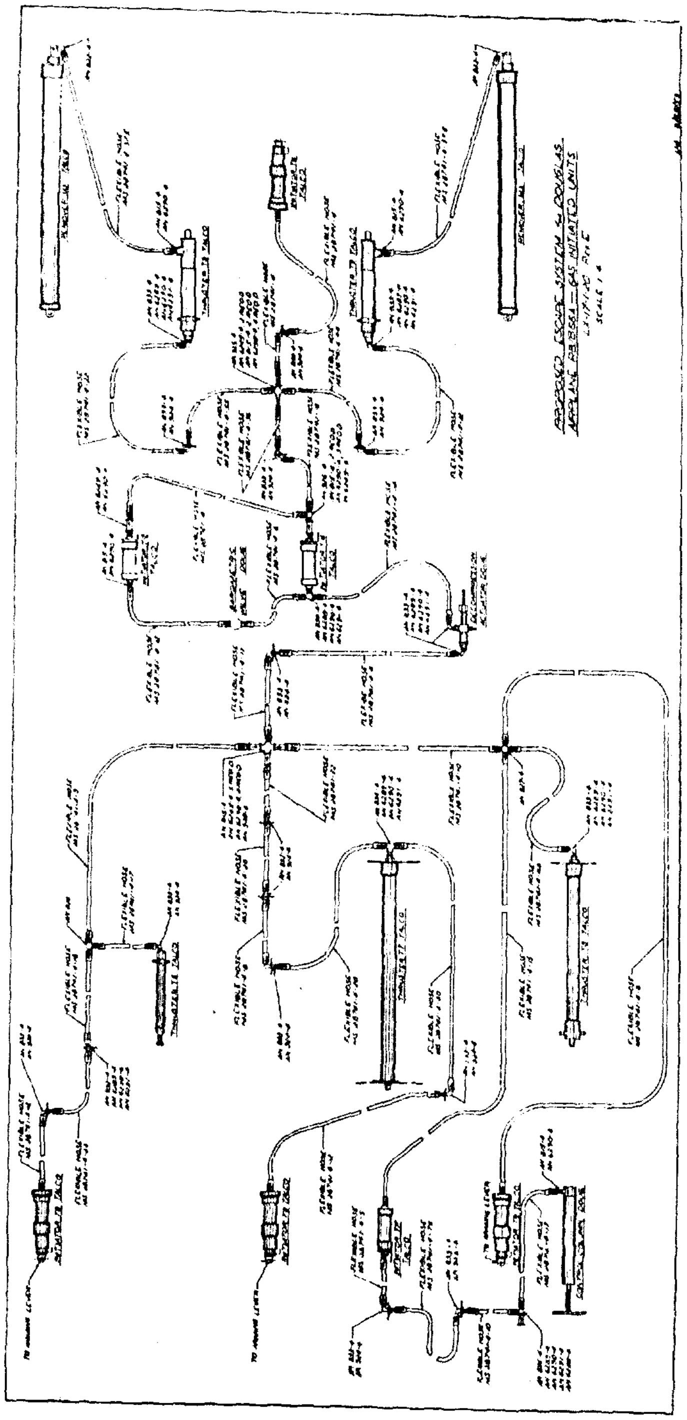


Figure 36. Schematic drawing of proposed propellent escape system

Neg. #24498-37
R-1183

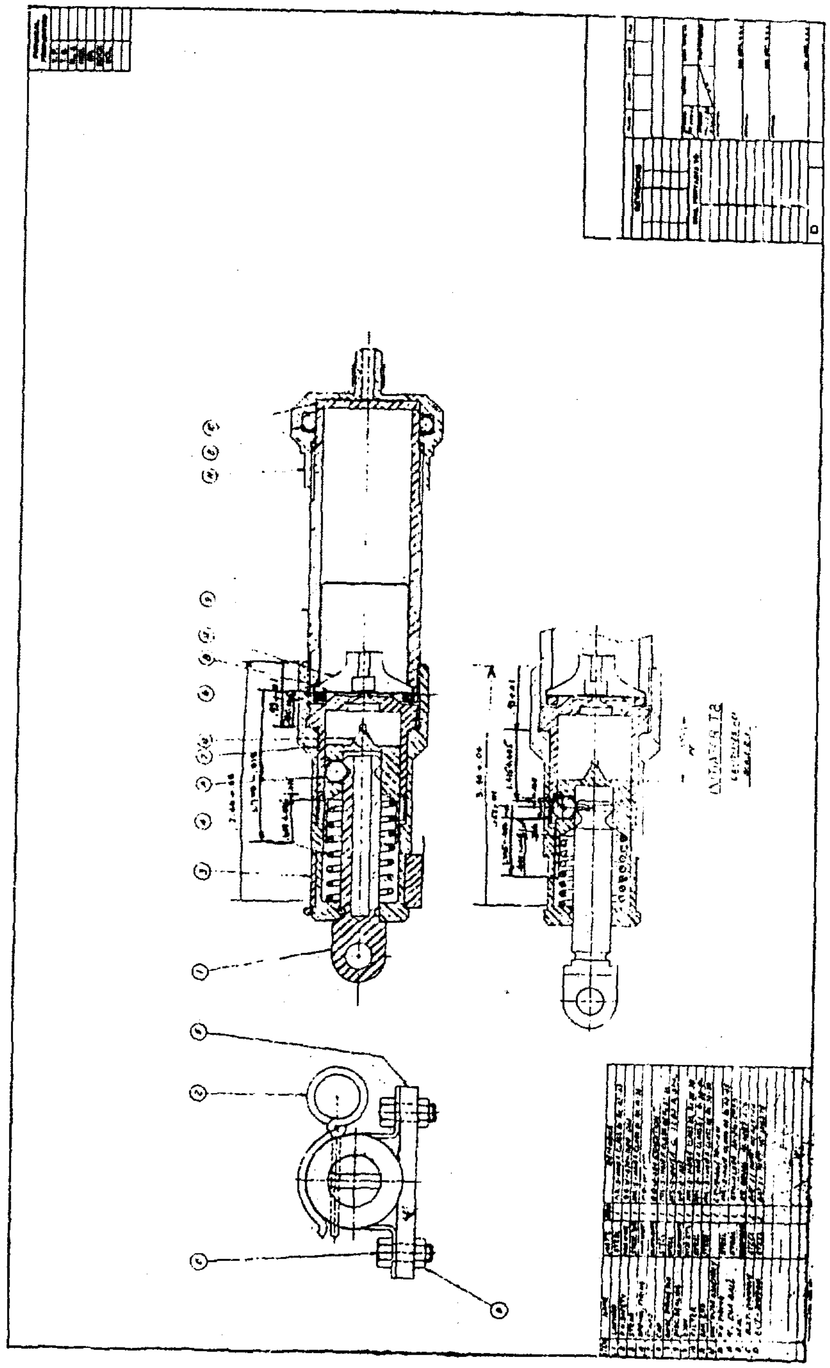


Figure 37. Design study of Initiator, T8

Neg. #24498-38
R-1183

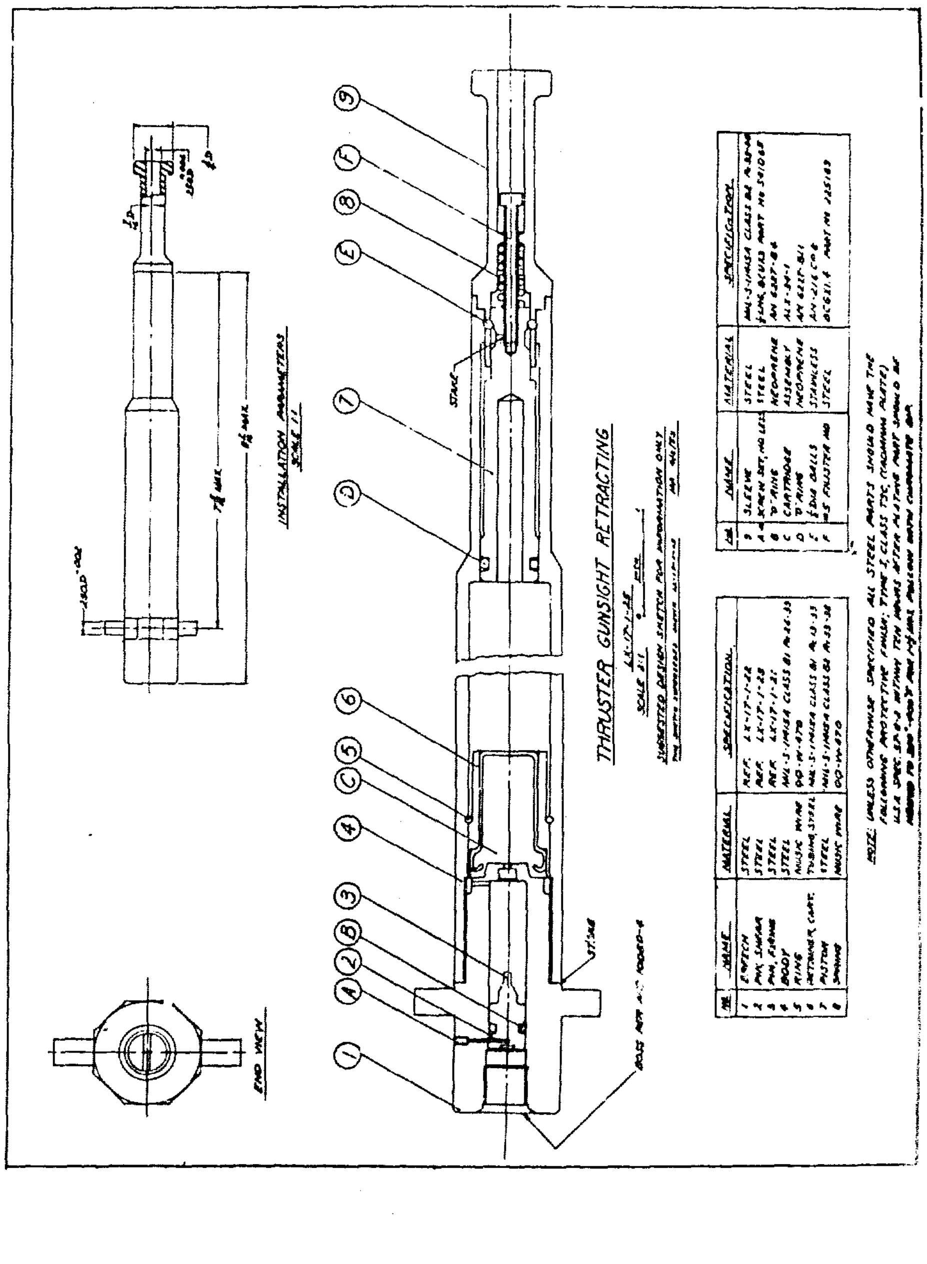


Figure 38a. Design study of Thruster, with Cartridge, T6 (gun sight retracting)

Neg. #24498-39
R-1183

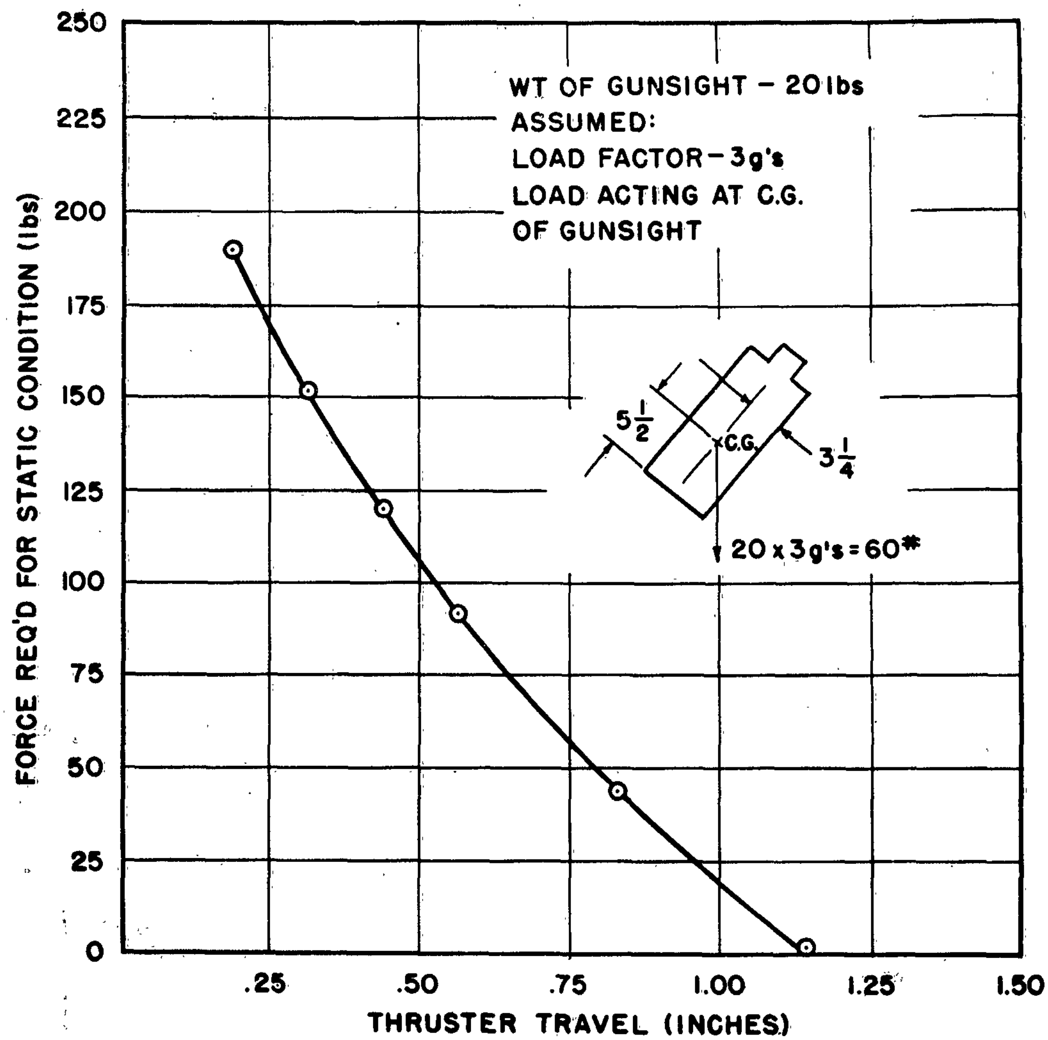
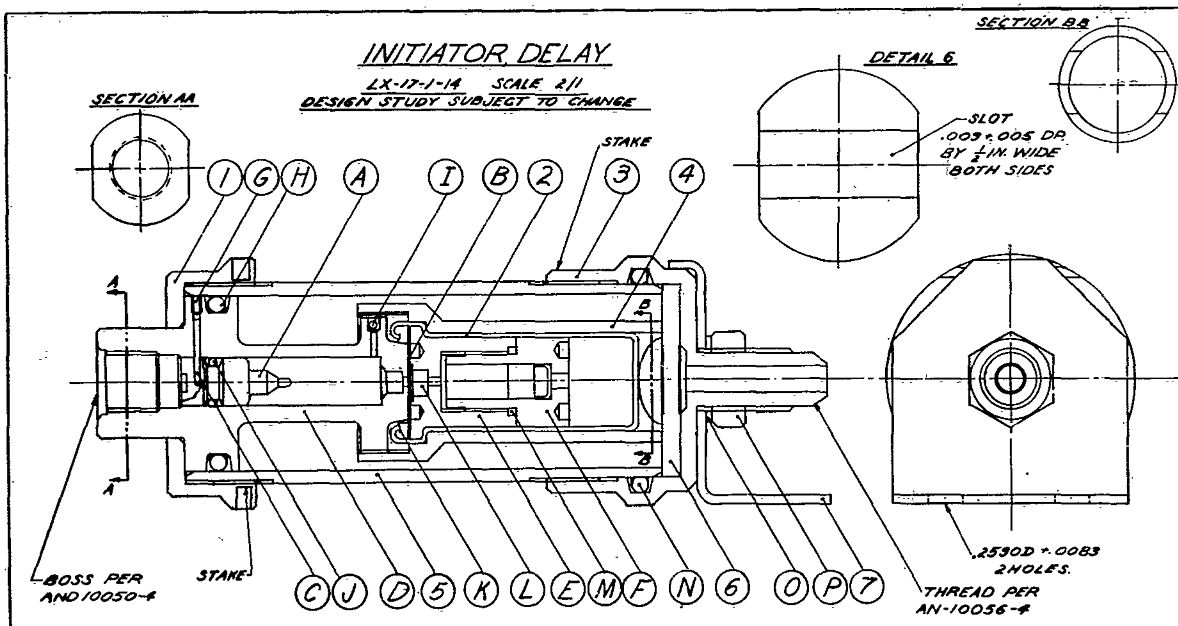


Figure 38b. Plot of thruster position vs force required for static condition of gun sight

Neg. #24498-40
R-1183



NOTE: FIRING PIN END .075D -.002 END SPHERICAL, PENETRATION TO BE .058 +.010

NO.	NAME	MATERIAL	DRAWING OR SPEC.
1	CAP, HEAD	STEEL	MIL-S-11415A CLASS B1 Rc 33-38
2	CASE, CARTRIDGE	ALUMINUM	QQ-A-318 Ref: ALX 8342
3	CAP, END	STEEL	MIL-S-11415A CLASS B1 Rc 33-38
4	RETAINER, CARTRIDGE	TUBING STL	MIL-S-11415A CLASS B2 Rc 33-38
5	BODY	TUBING STL	MIL-S-11415A CLASS A3 Rc 33-38
6	FILTER	STEEL	MIL-S-11415A CLASS B1 Rc 26-33
A	PIN FIRING	STEEL	MIL-S-11415A CLASS B1 Rc 42-45
B	DISC, SEALING	ALUMINUM	ALX-8345
C	PIN, SHEAR	DRILL ROD	QQ-S-00773 CLASS FSW110 Rc 15
D	GUIDE, FIRING PIN	STEEL	MIL-S-11415A CLASS B1 Rc 33-38
E	RETAINER, PRIMER	ALUMINUM	ALX-8343
7	BRACKET MOUNT	SHEET STL	MIL-S-11415A CLASS-B1-Rc 13-33

NO.	NAME	MATERIAL	DRAWING OR SPEC.
F	BODY, DELAY	ALUMINUM	ALX-8344
G	SCREW, SET, HEADLESS	STEEL	1/8 LNG., BCUX3 PART No 541065
H	"O" RING	NEOPRENE	AN 6227-B19
I	1/16 DIA. BALL	STAINLESS	AN 216 C1-4
J	"O" RING	NEOPRENE	AN 6227-B4
K	"O" RING	NEOPRENE	AN 6227-B12
L	PRIMER		M42; T4-2-66A
M	"O" RING	NEOPRENE	AN 6227-B5
N	"O" RING	NEOPRENE	AN 6227-B25
O	LOCK, WASHER 7/16 IN.	STEEL	BEAX2 PART No 121821
P	LOCK, NUT	STEEL	BBTX1 PART No 121349

HA 2/7/53

Figure 39. Design study of Delay-Initiator, T16

Neg. #24498-41
R-1183

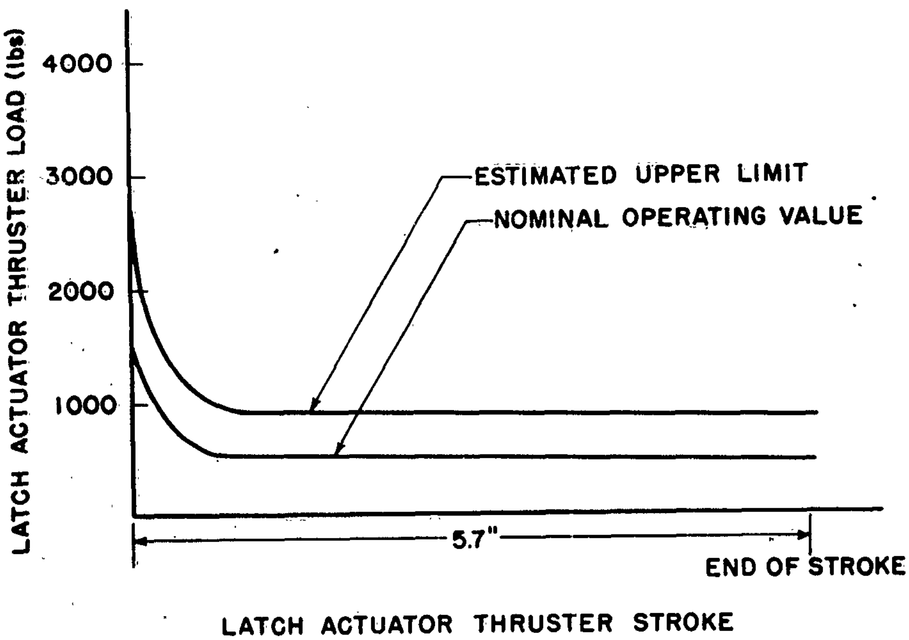


Figure 40. Plot of estimated required load stroke curves for the canopy jettison latch

Neg. #24498-42
R-1183

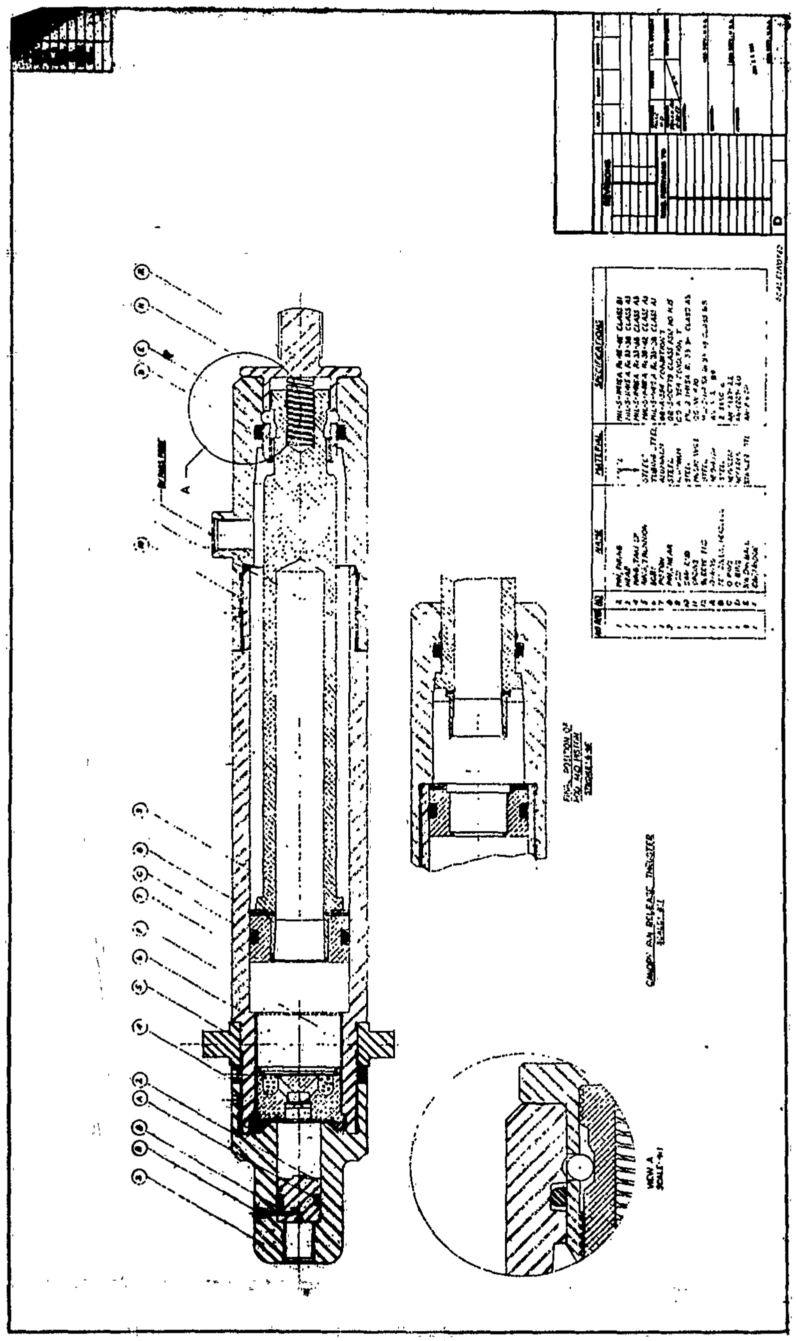


Figure 41. Design study of Thruster, with Cartridge, T9 (canopy pin release)

Neg. #24498-43
R-1183

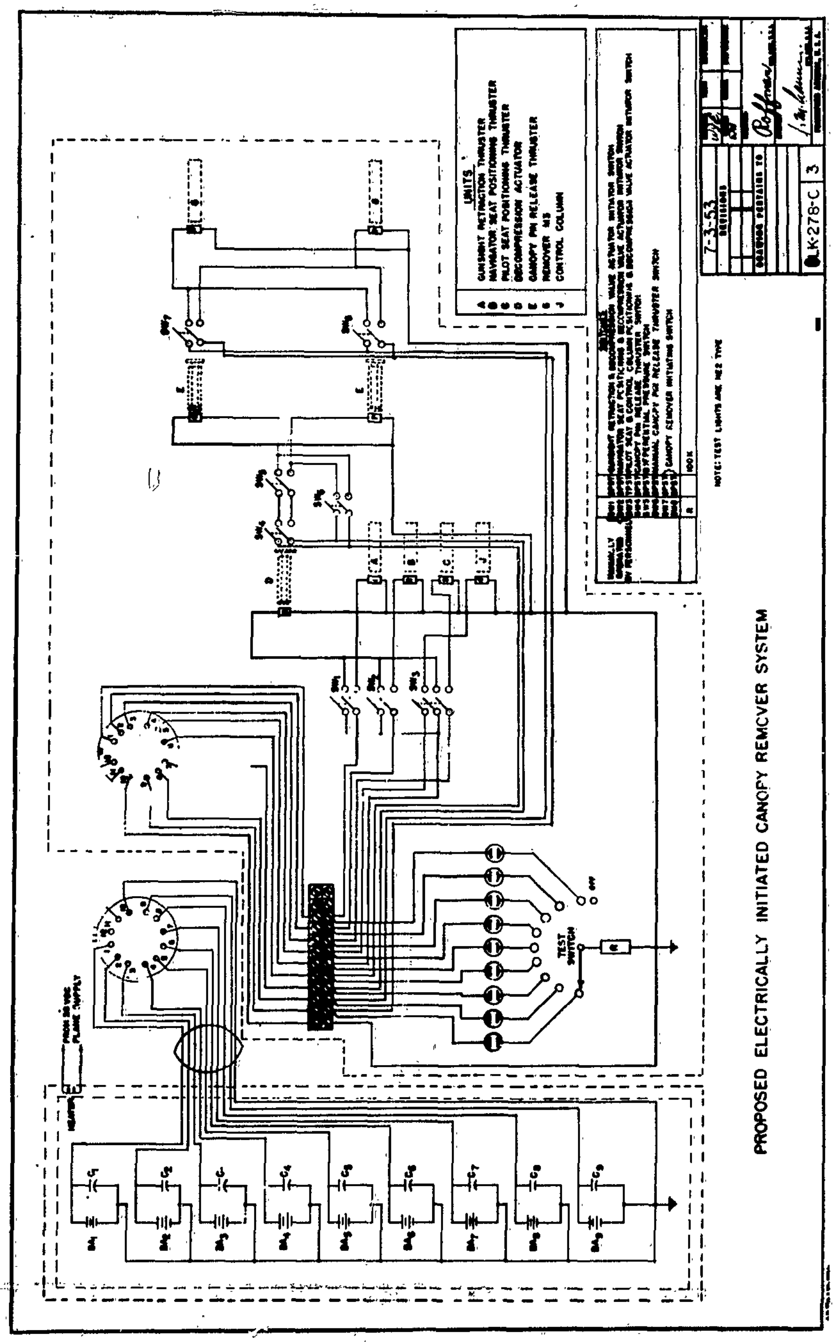


Figure 42. Schematic drawing of proposed electrical escape system

Neg. #24498-44
R-1183

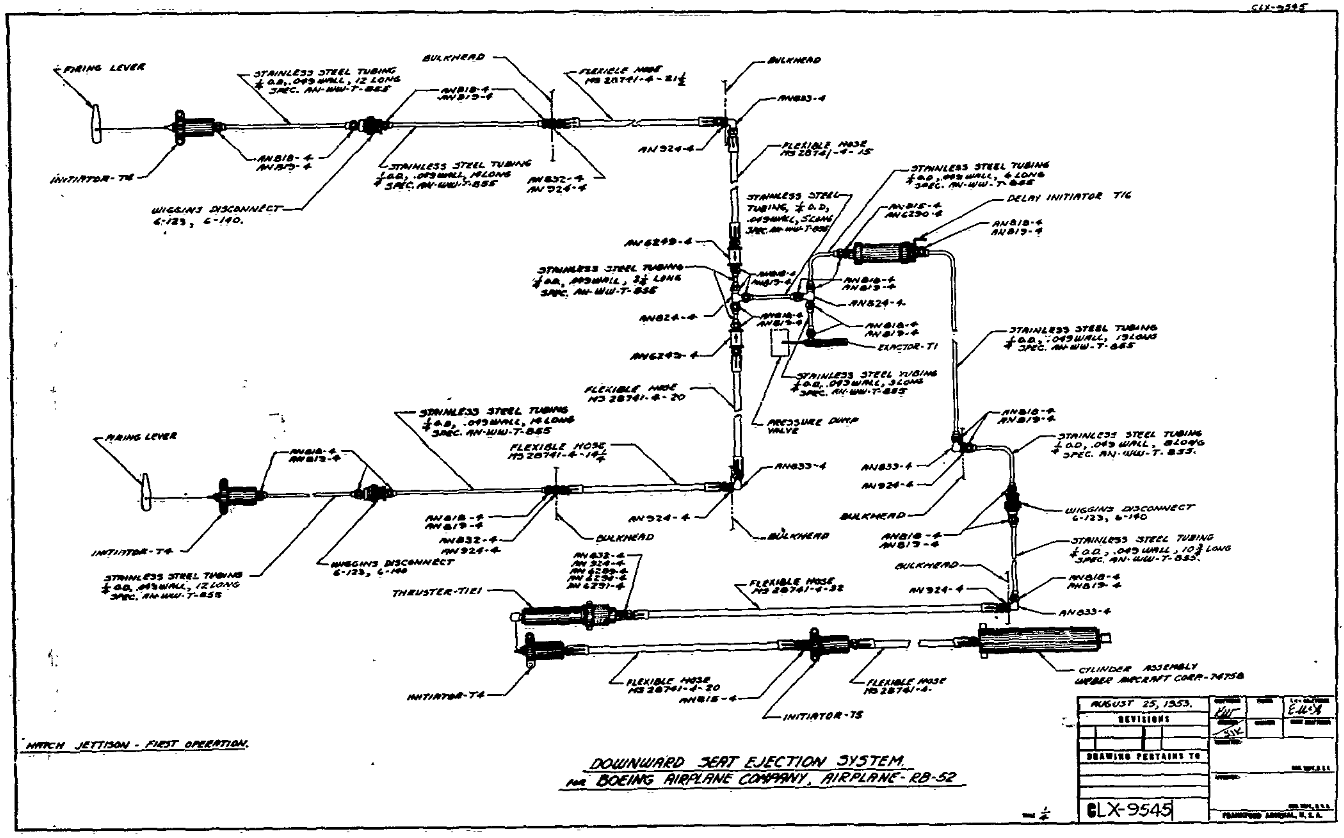


Figure 43. Schematic drawing of downward seat ejection system for RB-52 Airplane capsule

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R-1183

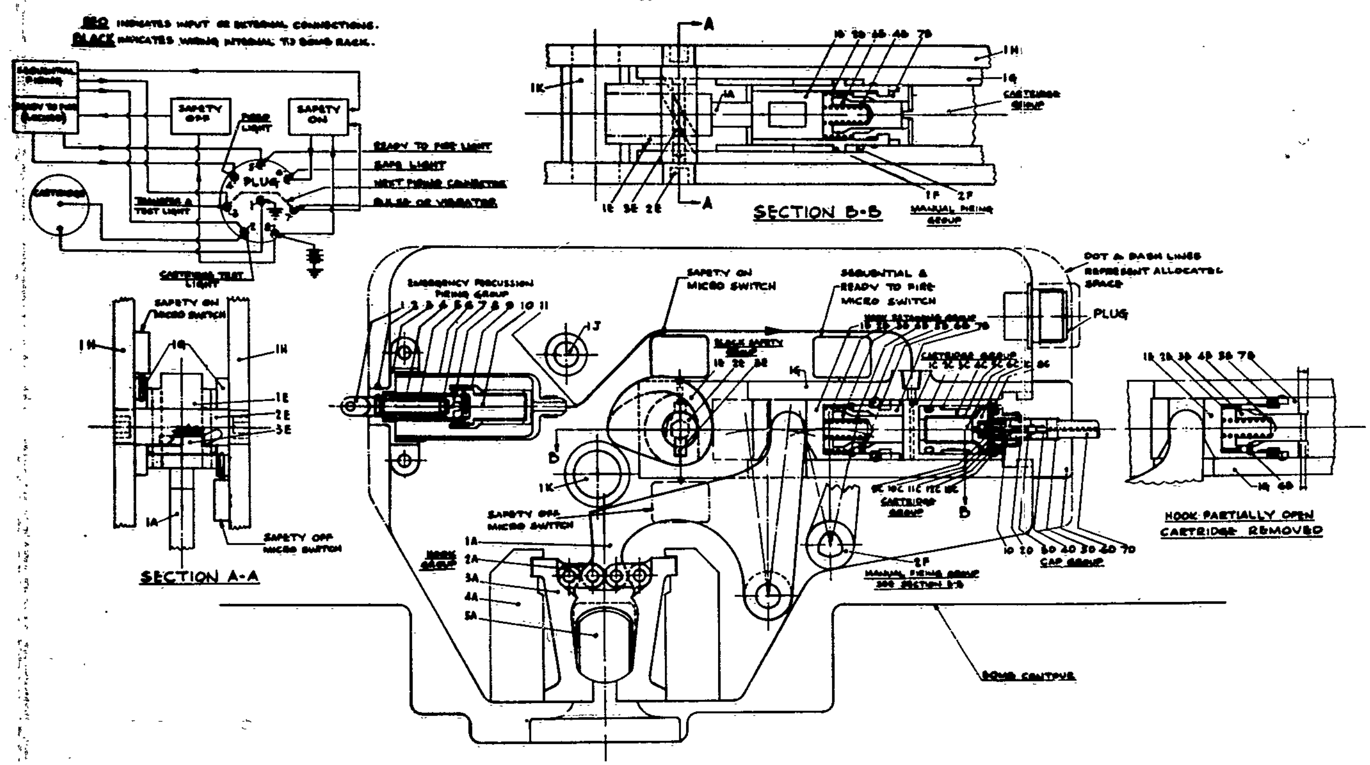


Figure 44. Release, Bomb, T6 (tentative design), bomb loaded

Neg. #24498-46
R-1183

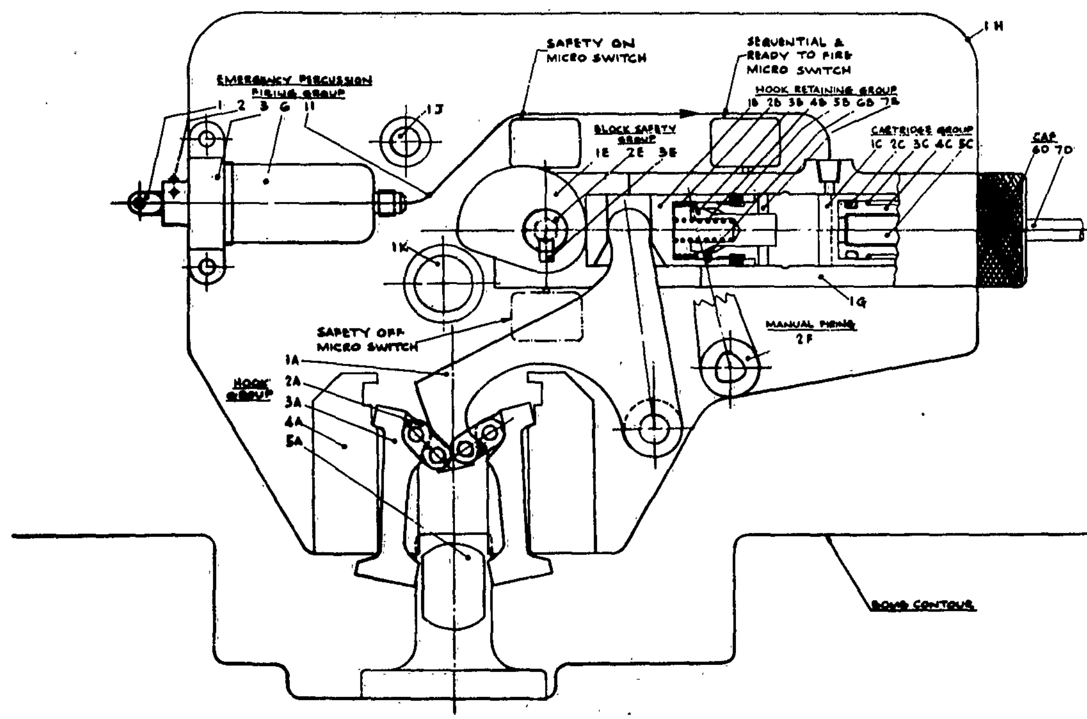


Figure 45. Release, Bomb, T6 (tentative design), bomb being loaded

Neg. #24498-47
R-1183

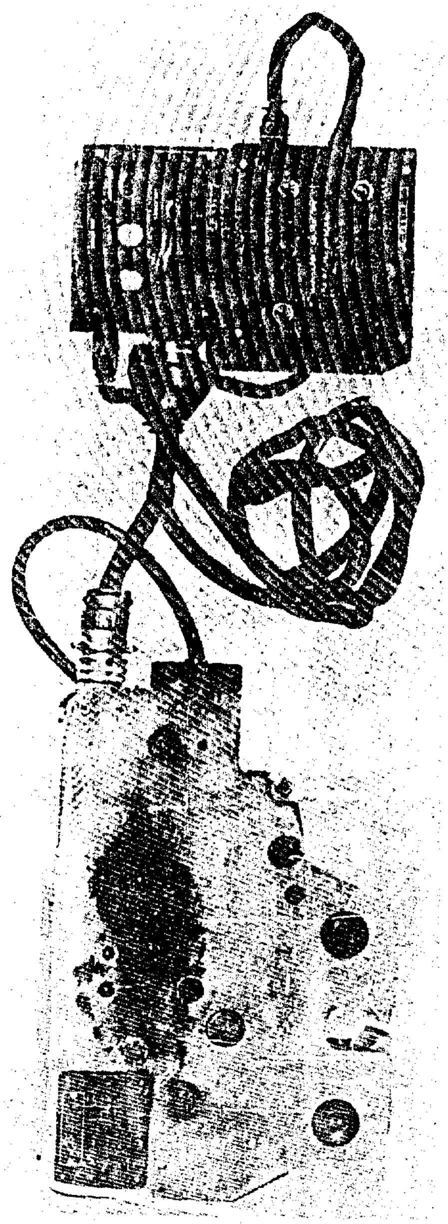


Figure 46. Release, Bomb, T6

Neg. #24498-48
R-1183

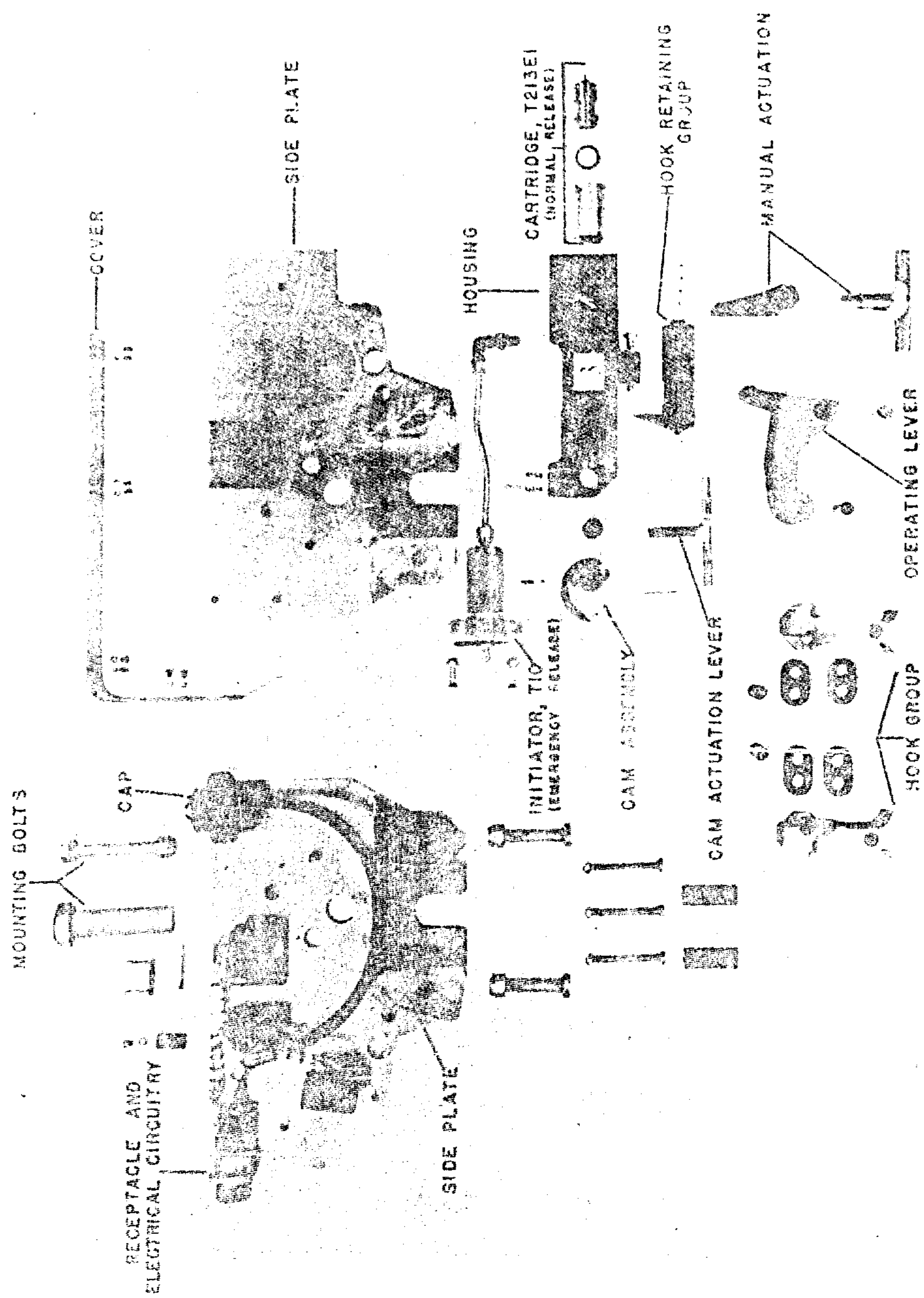


Figure 47. Release, bomb, T6; exploded view

Neg. #24498-49
R-1183

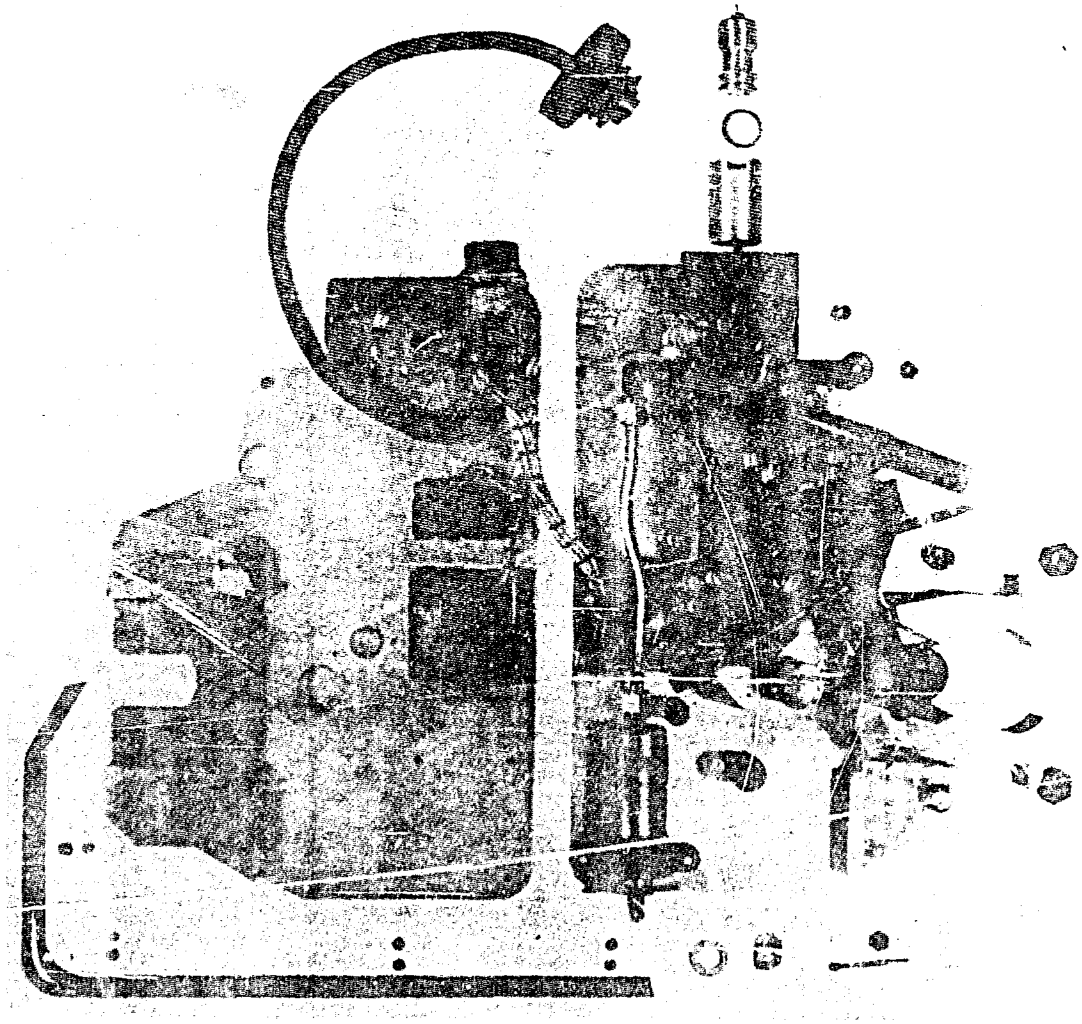


Figure 48. Release, Bomb, T6; bomb being loaded position

Neg. #24498-50
R-1183

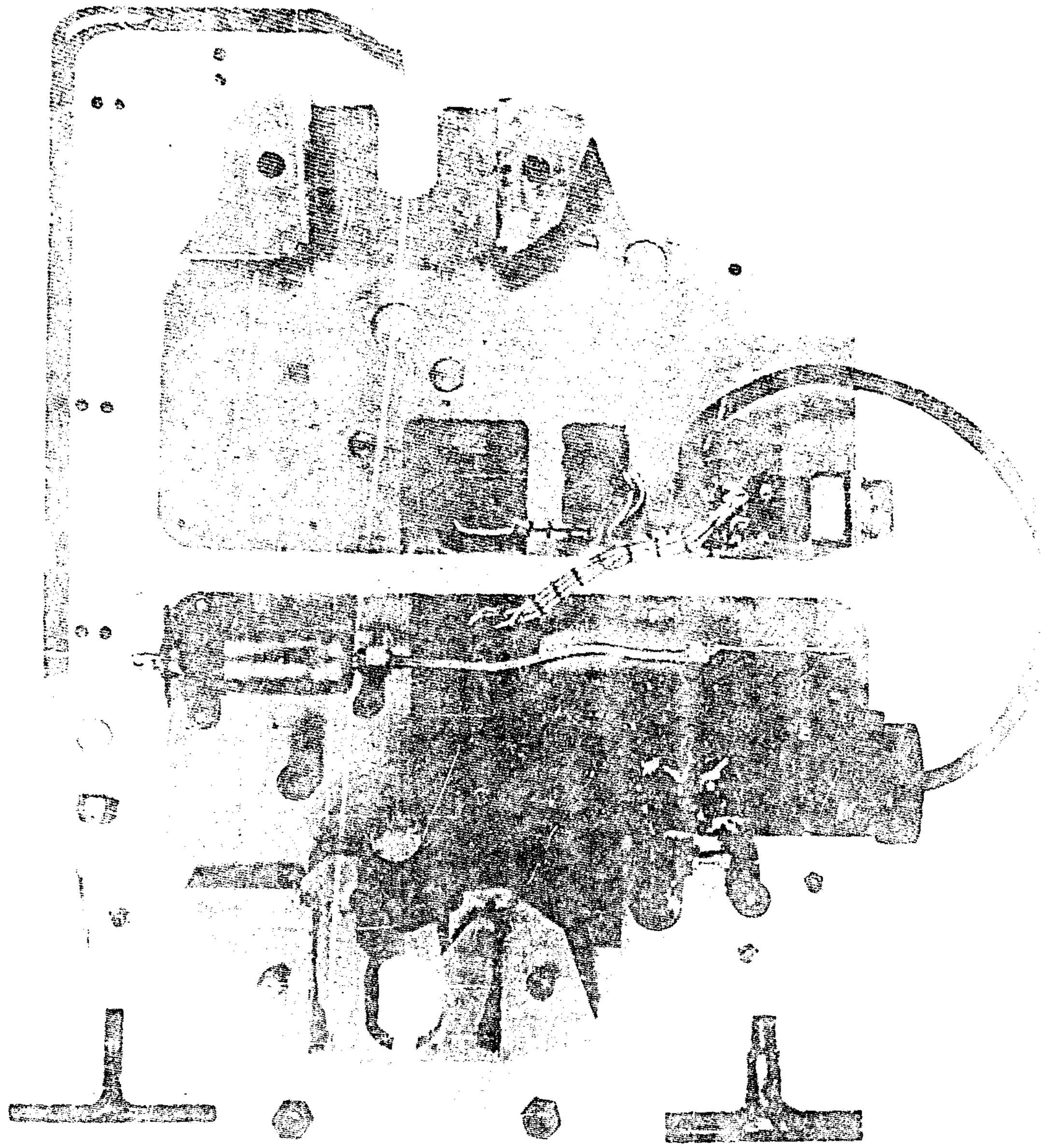


Figure 49. Release, Bomb, T6; bomb loaded position

Neg. #24498-51
R-1183

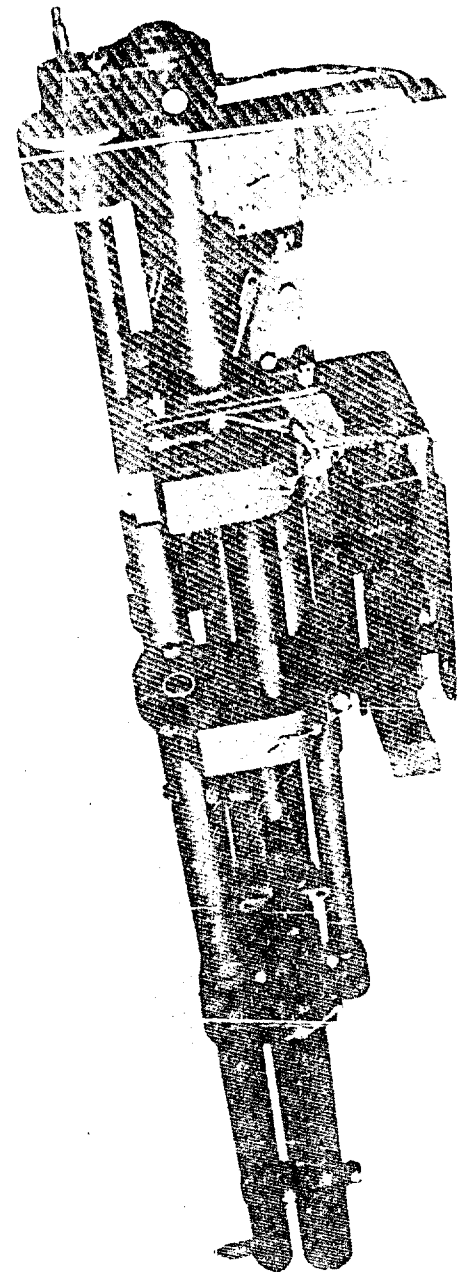


Figure 50. Projector, Photoflash Cartridge, T12 (low altitude)
(3/4 rear-right side)

Neg. #24498-52
R-1183

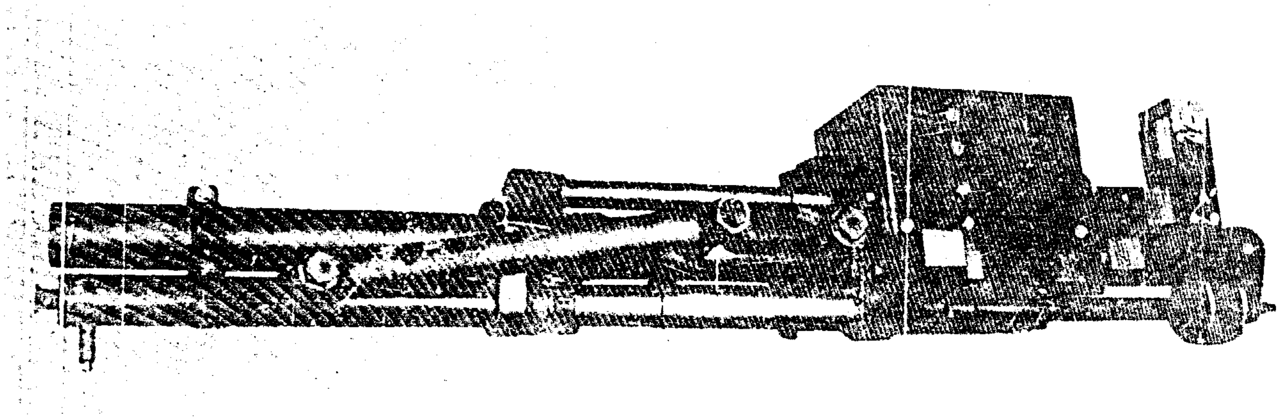


Figure 51. Projector, Photoflash Cartridge, T12 (low altitude)
(3/4 front-left side)

Neg. #24498-53
R-1183

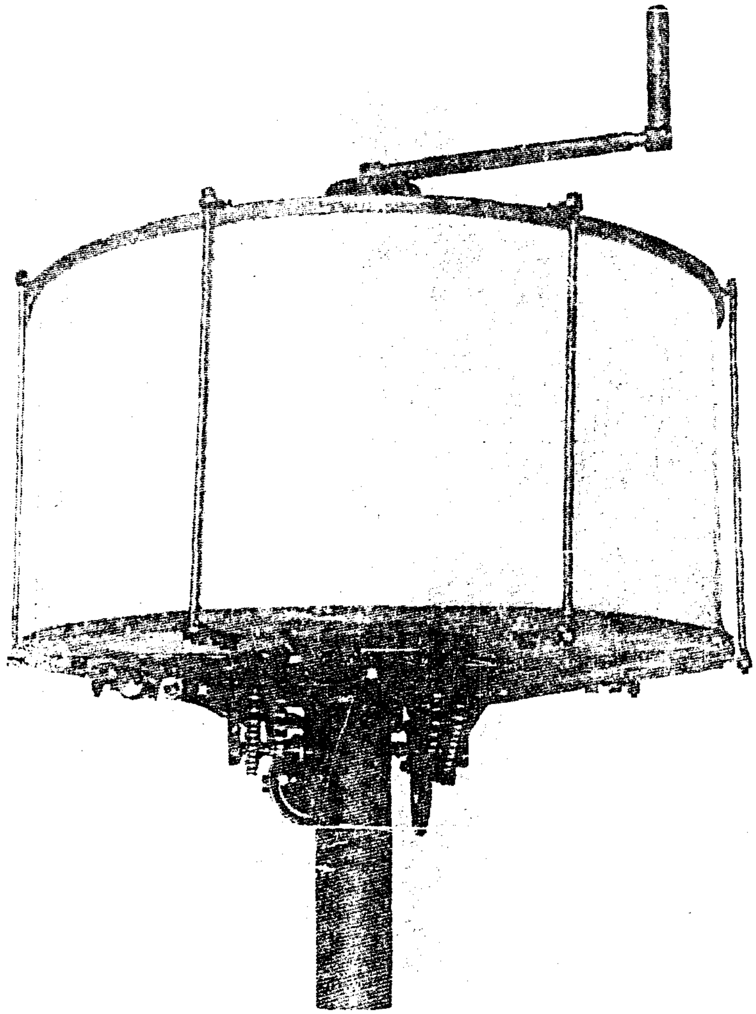


Figure 52. Projector, Photoflash Cartridge, T13 (medium altitude) (side view)

Neg. #24498-54
R-1183

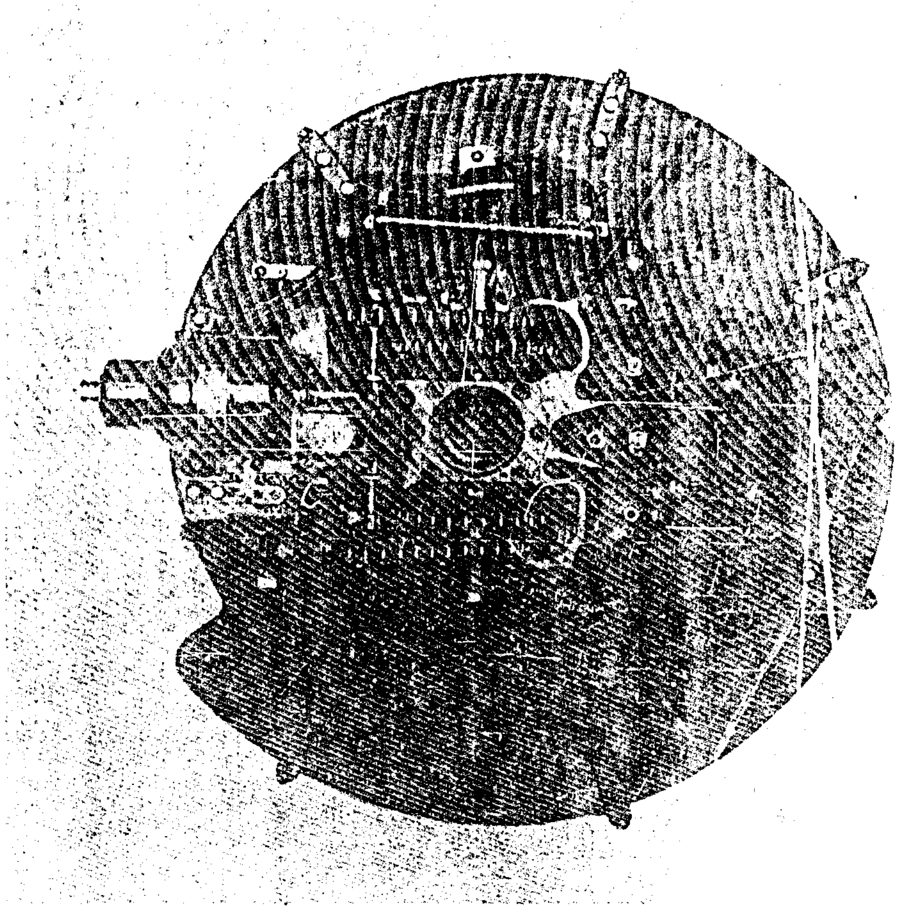


Figure 53. Projector, Photoflash Cartridge, T13 (medium altitude) (bottom view)

Neg. #24498-55
R-1183

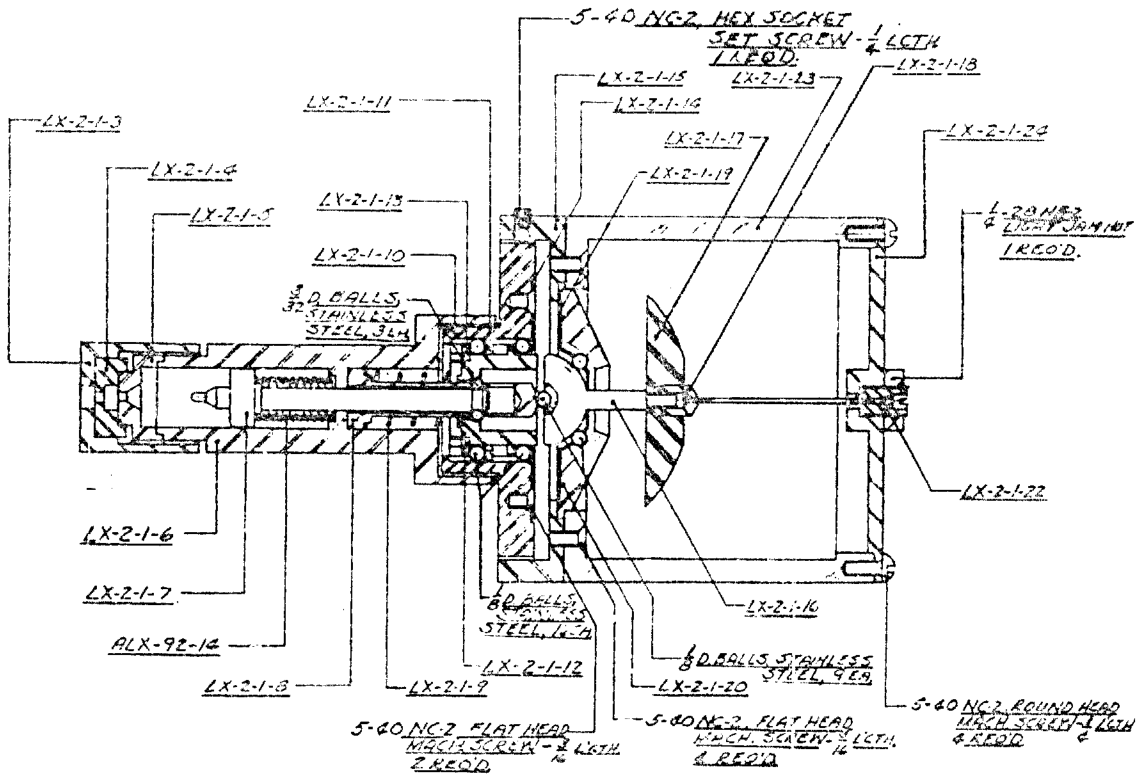


Figure 54. Assembly, Initiator, T6E3, test

Neg. #24498-56
R-1183

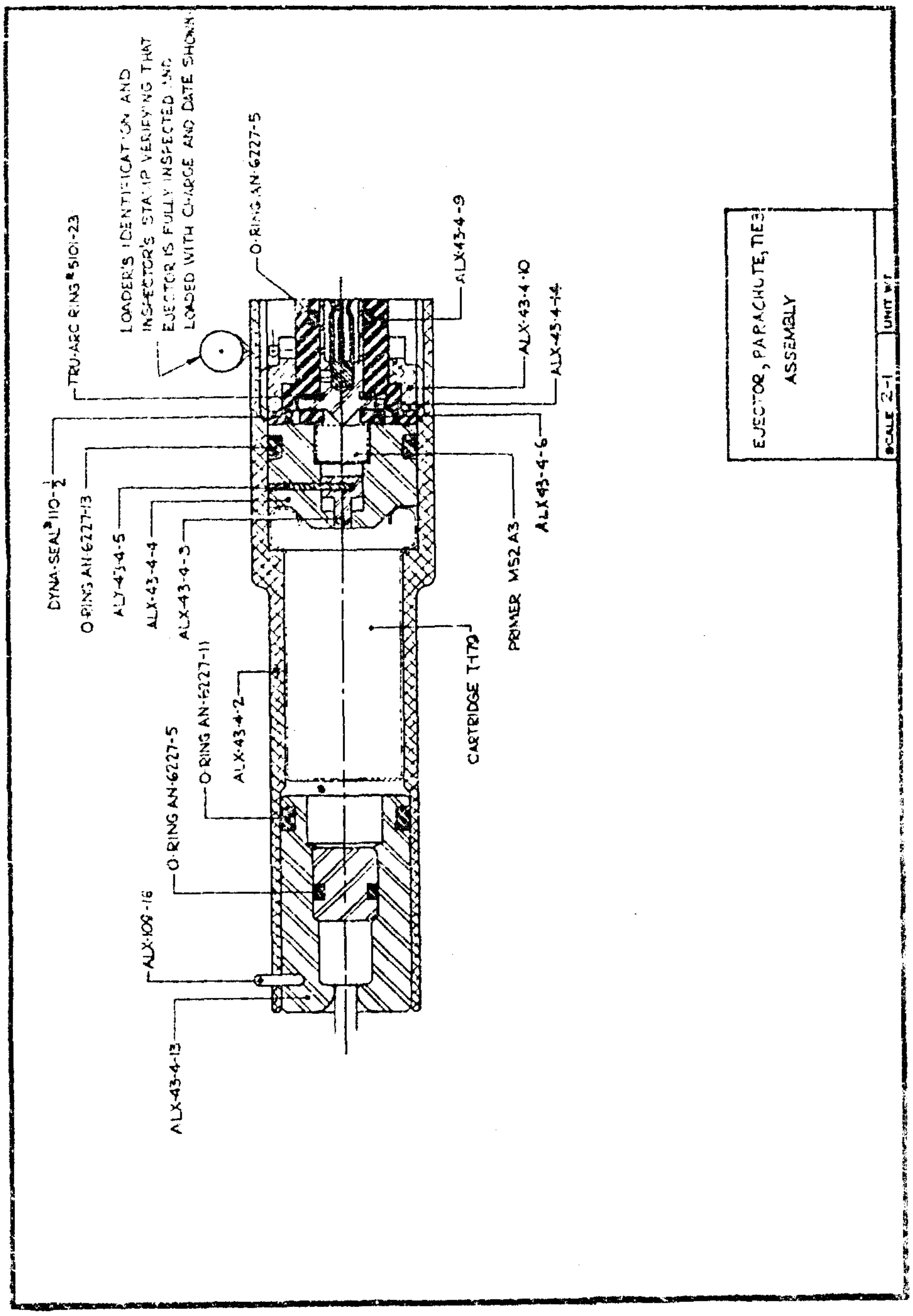


Figure 55. Ejector, Parachute, T1E3, assembly

Neg. #24498-57
R-1183

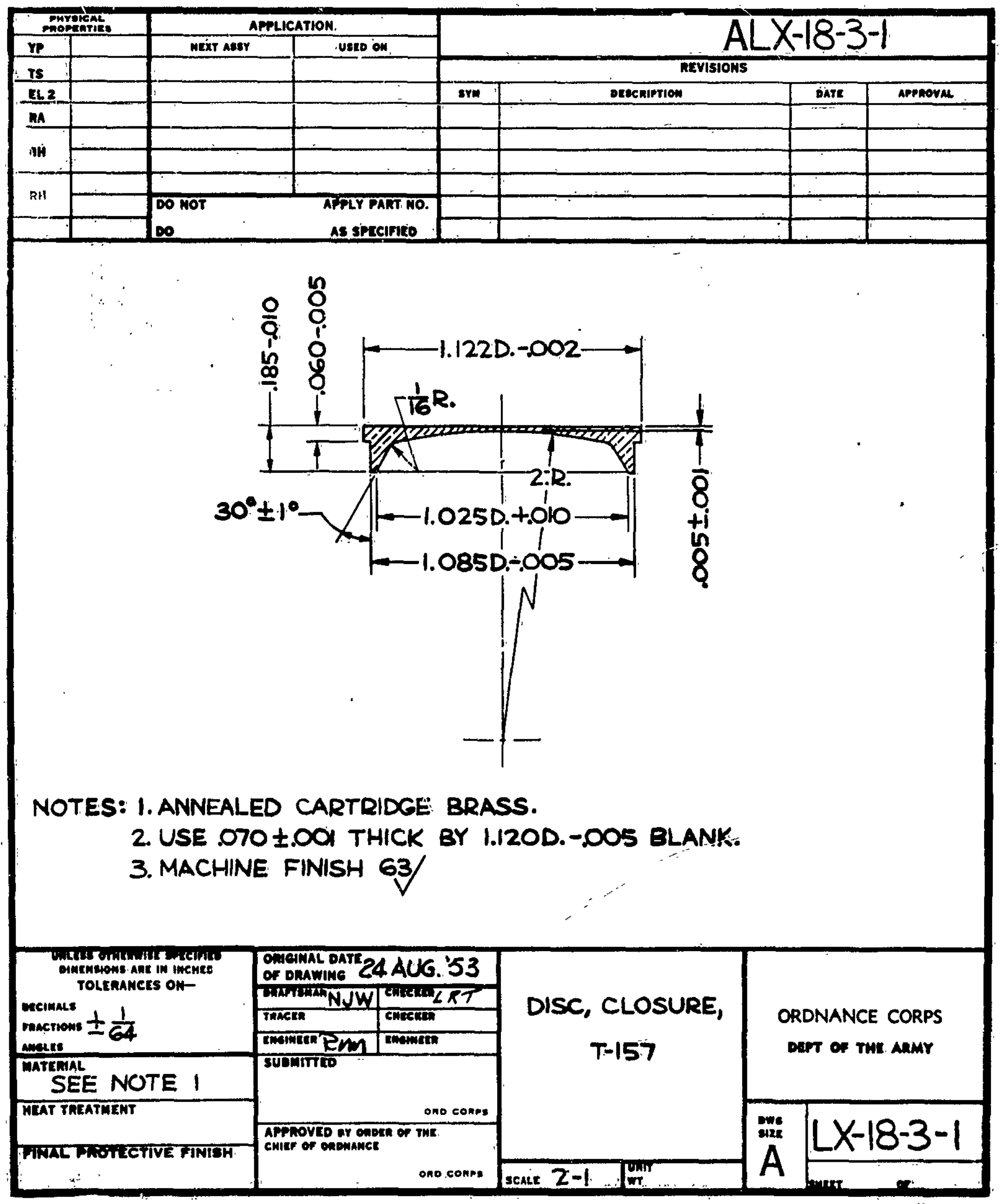
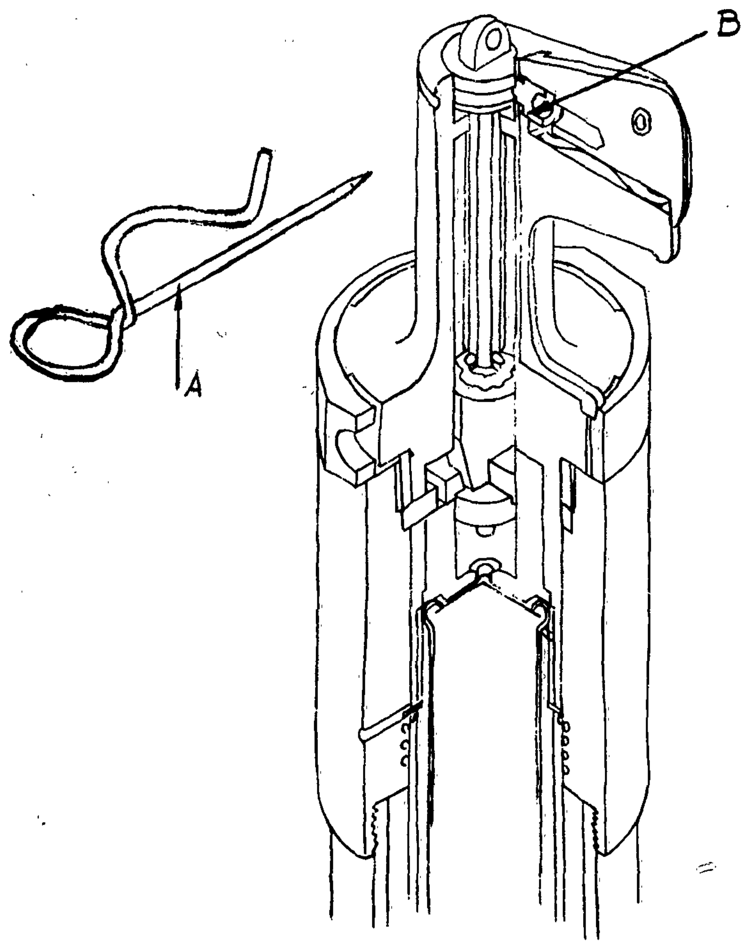


Figure 56. Disc, closure, Cartridge, Catapult, T157 (M57)



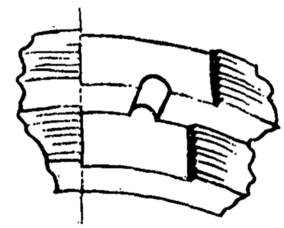


FIGURE A

A key between the locking ring and the block insures rotational alignment of the two pieces (figure 2-arrow A).

ARROW A)

FIGURE A

A general view of the upper end of the catapult is shown with the safety pin about to be inserted (arrow A). The detent pin that engages the sear pin groove also prevents movement of the unlocking trigger (arrow B).

: A

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e block
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pieces
A).

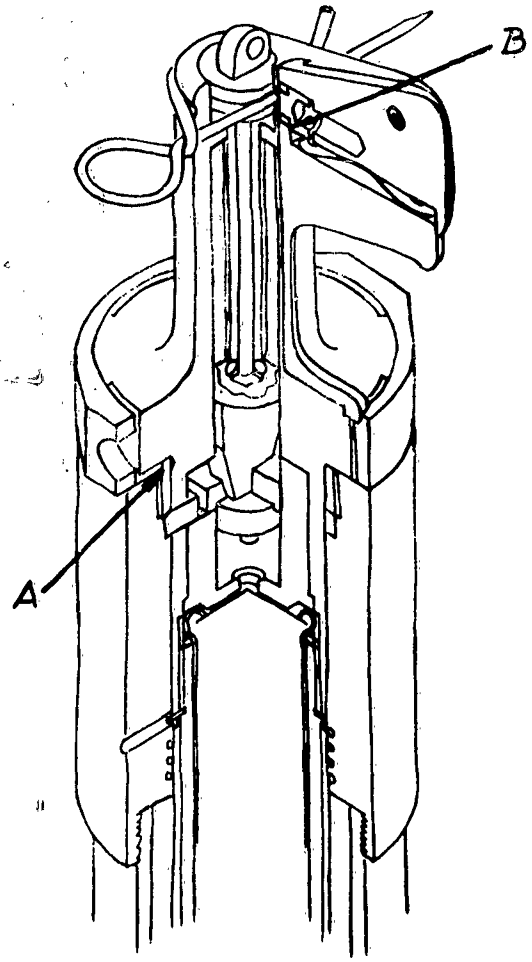

FIGURE B

The safety pin engages the groove in the sear pin, thu preventing accidental firing. The safety pin also displaces the detent pin far enough to clear the unlocking trigger (arrow B).

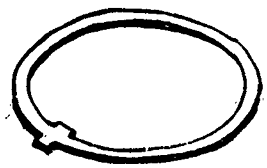

FIGURE B

A washer with diameters equal to those of the telescoping tube has internal and external keys to insure rotational alignment of the block and inside tube.

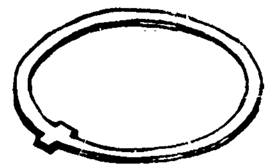

FIGURE B

A washer with diameters equal to those of the telescoping tube has internal and external keys to insure rotational alignment of the block and in inside tube.

When the un
the round k
permitting
the trunnion

Figure 57. Disassembly, Catapult, T15

2

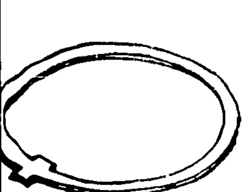

FIGURE B

vasher with diameters
ıal to those of the
escoping tube has in-
nal and external keys
insure rotational align-
nt of the block and in
ide tube.

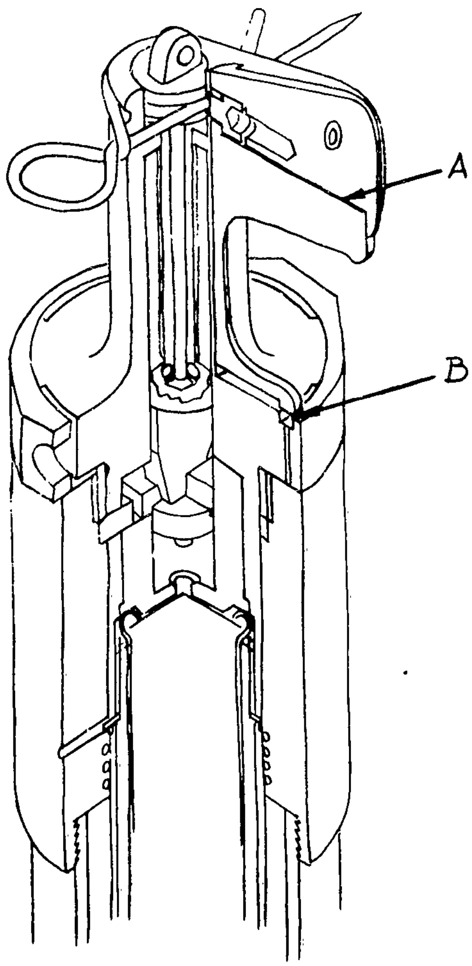

FIGURE C

When the unlocking trigger is lifted (arrow A) the round key is cleared from its recess, permitting rotation of the block relative to the trunnion ring (arrow B).

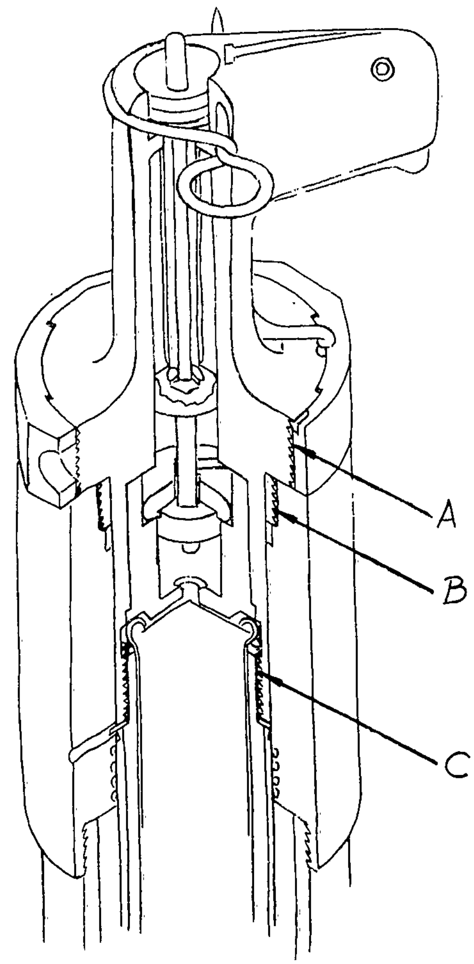

FIGURE D

The handle is rotated in a counter-clockwise direction 45°, thus unlocking three separate interrupted thread systems;

a, Block and trunnion ring (arrow A)
b, Locking ring and stop ring (arrow B)
c, Block and inside tube (arrow C).

isassembly, Catapult, T15

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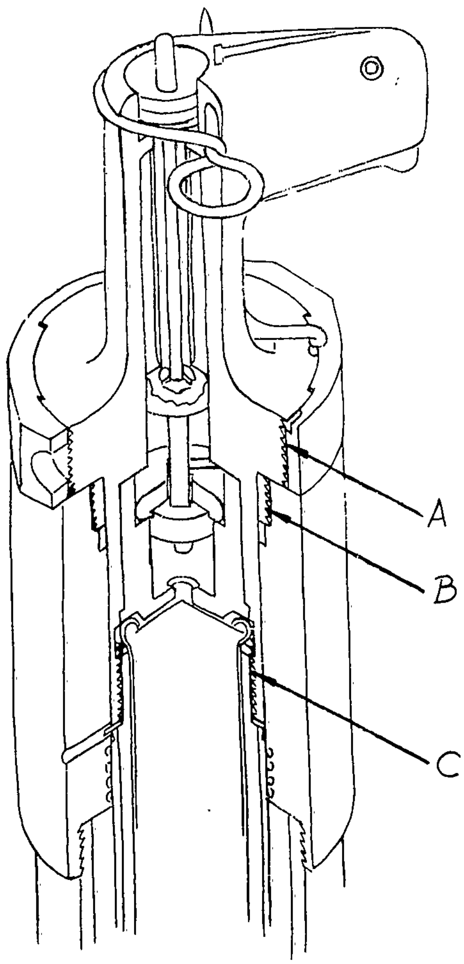

FIGURE D

The handle is rotated in a counter-clockwise direction 45°, thus unlocking three separate interrupted thread systems;

a, Block and trunnion ring (arrow A)
b, Locking ring and stop ring (arrow B)
c, Block and inside tube (arrow C).

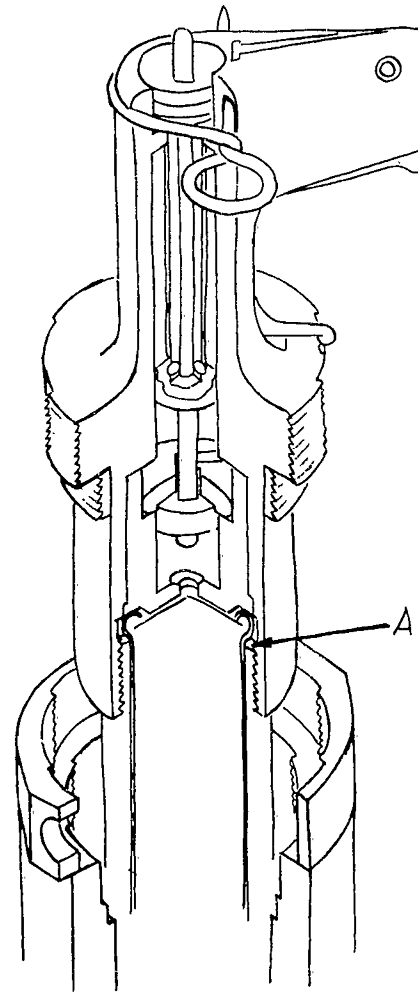

FIGURE E

The head assembly is lifted up and out, the plastic shock ring acting as an extractor for the cartridge (arrow A).

4

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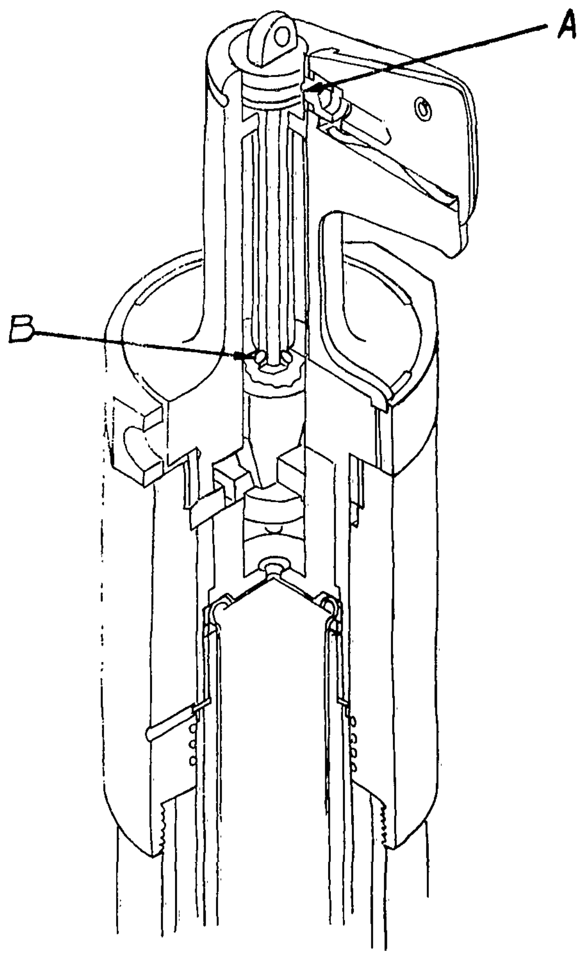


FIGURE A

A general view of the upper end of the catapult is shown. The sear pin is restrained by a detent pin in the handle. This pin has a small protrusion that engages the safety pin groove in the sear pin (arrow A). The force of the firing pin spring is transmitted thru the locking balls against the sear pin (arrow B), thus keeping the firing head cocked.

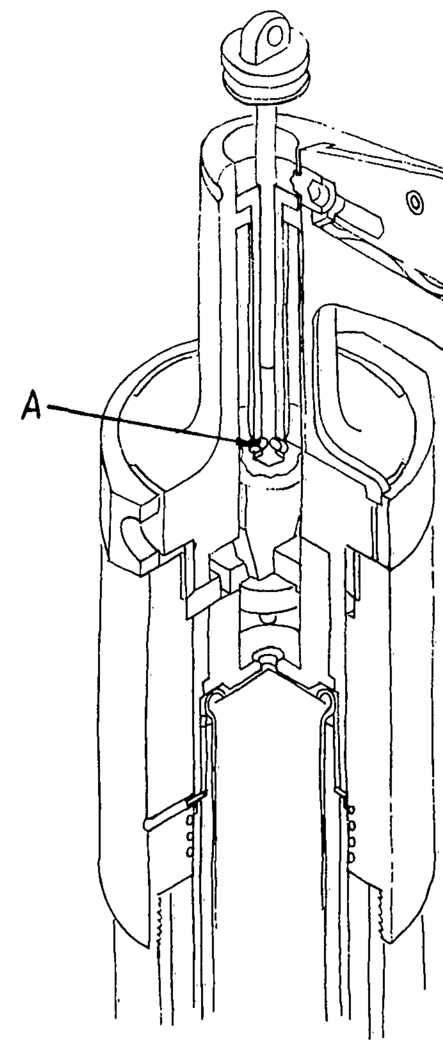
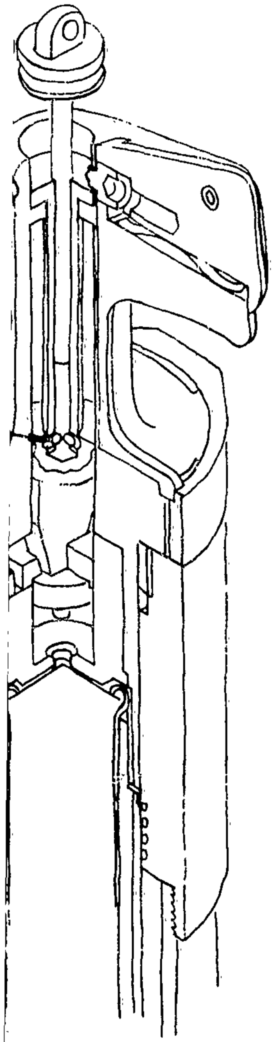


FIGURE B

The sear pin is lifted by the actio
pilot in firing the catapult. The b
leased and the firing pin is free t
(arrow A). The detent pin releas
pin with a slight pull.



IGURE B

ifted by the action of the
catapult. The balls are re-
ring pin is free to move
detent pin releases the sear
pull.

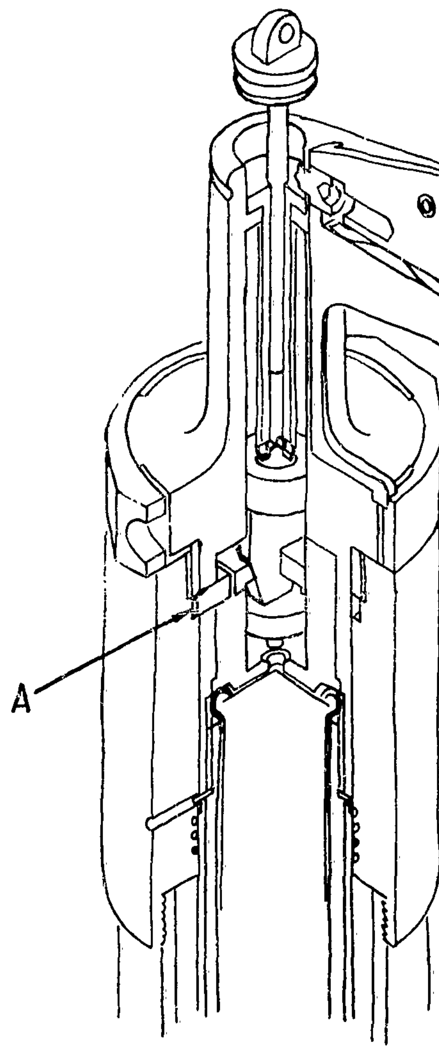


FIGURE C

The firing pin spring forces the firing pin down, causing the latches to be retracted (arrow A).

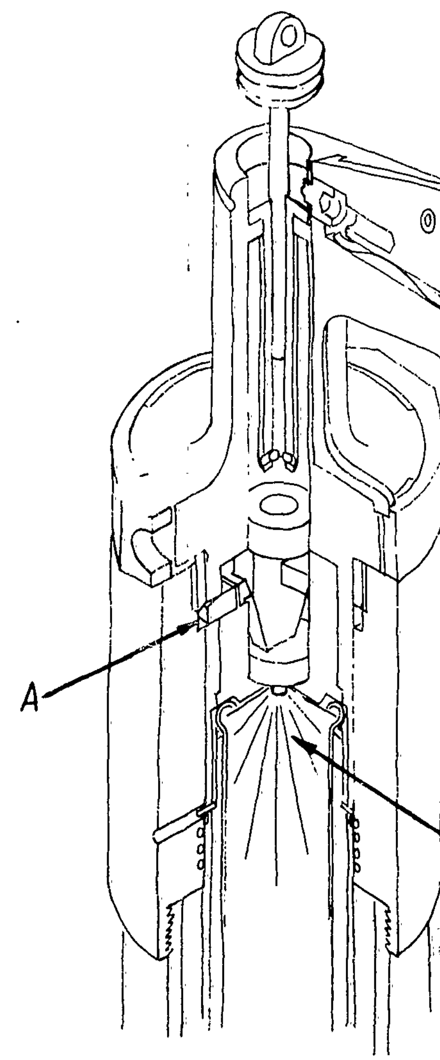


FIGURE D

The latches are fully retracted before the firing pin strikes the primer (arrow B).

Figure 58. Operation, Catapult, T15

2

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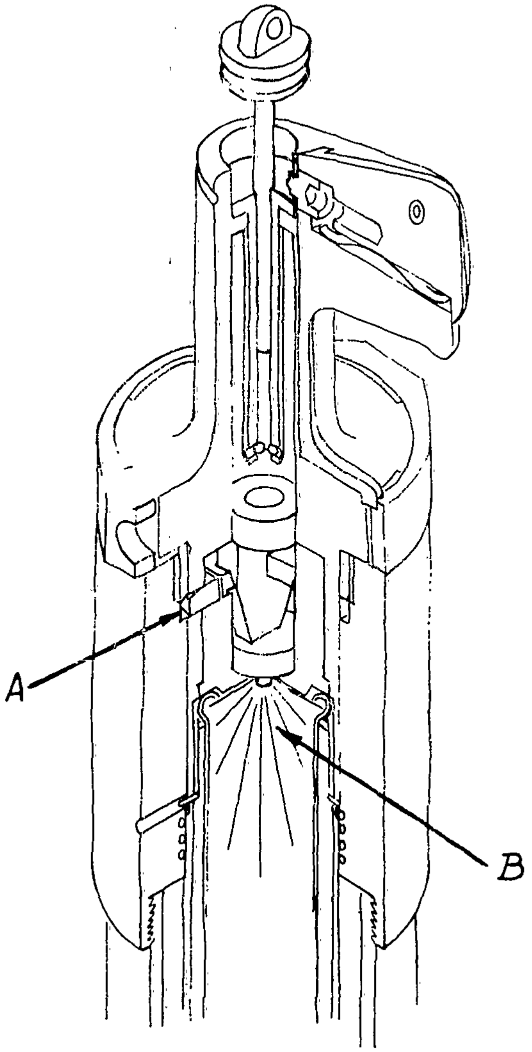

FIGURE D

The latches are fully retracted (arrow A) before the firing pin strikes the cartridge primer (arrow B).

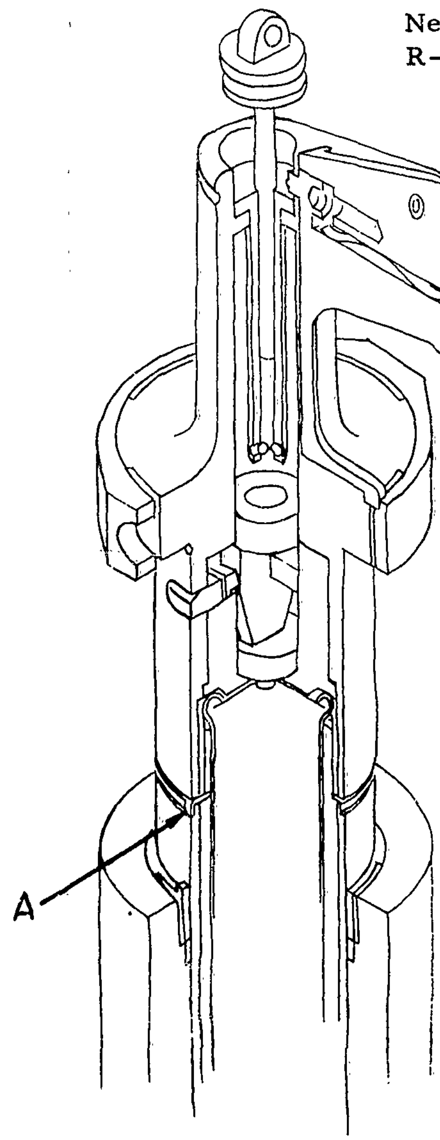

FIGURE E

The key on the washer that prevents relative rotation of the stop ring and the inside tube is bent down as the tubes begin to move (arrow A).

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